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Guidance tool for good practices in bird conservation in the development of renewable energies

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In collaboration with: Birdlife International & Energy Task Force (CMS)

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ACRONYMS

BNG	Biodiversity Net Gain
CMS	Convention on Migratory Species
CSP	Concentrated solar power
EC	European Commission
EIA	Environmental impact assessment
EU	European Union
GPS	Global Positioning System
GW	Gigawatt
IBA	Important Bird and Biodiversity Area
IEA	International Energy Agency
IFC	International Finance Corporation
INCA	Integrated Natural Capital Accounting
IRENA	International Renewable Energy Agency
IUCN	International Union for Conservation of Nature
MHF	Mitigation Hierarchy Framework
MW	Megawatt
NFRD	Non-Financial Reporting Directive
NGO	Non-governmental organisation
OECD	The Organization for Economic Co-operation and Development
PBR	Potential biological removal
PV	Photovoltaic
PVA	Population viability analysis
SEA	Strategic Environmental Assessment
SDOD	Shutdown on demand

ICONS


Guidelines
Sensitivity maps
Protected areas
Biological information: wildlife and habitats
Software or tools
Databases and Repositories
Wind farms
Photovoltaic solar plants
Electricity grid or power lines

EXECUTIVE SUMMARY

This guidance, prepared under the Bern Convention mandate, responds to the urgent need to reconcile two global imperatives: the rapid deployment of renewable energies to mitigate climate change and the equally critical obligation to conserve biodiversity. Governments are reminded that while renewable energy is indispensable for addressing climate change policies, poorly planned deployment can result in habitat loss, disturbance and displacement of biodiversity, increase bird and bat mortality, and produce barrier effects on migration routes. The document positions biodiversity protection not as an obstacle, but as an integral element of a sustainable and publicly legitimate energy transition. This document is designed to provide the necessary tools to the stakeholders that ensure the transition to renewables does not undermine the very ecological foundations on which long-term sustainability depends.

Governments are urged to embed biodiversity objectives within national renewable energy strategies, long-term energy plans, and climate policies. Strategic planning should anticipate the expansion of renewables at the landscape scale, identifying areas of high sensitivity for birds such as wetlands, breeding colonies, and migratory flyways, and steering development away from these zones. The use of sensitivity mapping tools and spatial planning instruments is encouraged to guide decision-making and reduce conflicts before projects reach the permitting stage.

The recommendations call for governments to embed ecological considerations into national renewable energy strategies, to employ spatial planning tools that direct projects away from sensitive areas, and to require robust environmental impact assessments that address cumulative effects. The document further emphasizes the importance of applying the mitigation hierarchy, with avoidance of ecological harm as the foremost principle, and adopting adaptive management approaches that allow projects to respond to new evidence over time. It highlights the role of technological innovation, including automated monitoring systems, bird-friendly turbine and grid designs, and safer solar array layouts, as vital means to reduce risks while maintaining energy efficiency. Long-term monitoring and the open sharing of results are identified as necessary for accountability and cross-border cooperation, given that many of the affected species are migratory.

In terms of governance, the guidance underscores the necessity of inter-ministerial coordination, strong regulatory capacity, and the active involvement of the public in decision-making. Transparent processes, meaningful participation of local communities, and enforcement of standards will strengthen trust and reduce conflict between conservation and development objectives.

In conclusion, the guidance underscores that meeting climate objectives through renewable energy expansion and safeguarding biodiversity are not mutually exclusive but mutually reinforcing goals. Governments that adopt these recommendations will not only reduce the risk of legal disputes and project delays but also position themselves as leaders in building a truly sustainable energy future. The public, as both beneficiaries of clean energy and custodians of natural heritage, will gain confidence that the transition to renewable energy is being carried out responsibly. The Bern Convention thus offers a unifying framework for integrating bird conservation into energy policies, ensuring that Europe’s contribution to tackling climate change also secures the survival of its avian diversity for generations to come.

1 Introduction

1.1 Context and scale of the problem

Over the past three decades, renewable energy has transformed from a niche technology to the cornerstone of global efforts to combat climate change. Solar, wind, and associated grid infrastructure have reshaped energy systems, with measurable impacts on emissions, policy landscapes, energy security, affordability and regional energy strategies.

In this current context of the climate emergency, the acute need for energy from sustainable sources implies that renewable energy facilities are often set up through fast-tracked processes, sometimes to the detriment of nature and biodiversity conservation. This tension is evident in the environmental policy of the European Union, where recent years have seen a relaxation of certain safeguards, such as streamlining Environmental Impact Assessment (EIA) procedures to accelerate renewable energy deployment. Thus, the European Commission's recent proposal for the REPowerEU Plan highlights the need to balance rapid renewable energy expansion with the protection of habitats under the Birds and Habitats Directives (European Commission, 2022). This illustrates the challenge of reconciling climate mitigation goals with biodiversity preservation within EU environmental law. Furthermore, the development of renewable energies could be an opportunity to jointly and strategically address the energy transition and nature restoration.

Being aware of the situation, the Standing Committee of the Convention on the Conservation of European Wildlife and Natural Habitats adopted the Recommendation No. 109 on minimizing adverse effects of wind power generation on wildlife and the guidance of 2003 on environmental assessment criteria and site selection issues related to wind-farming (2004) as well as the best practice guidance on integrated wind farm planning and impact assessment presented to the 33rd meeting of the Bern Convention Standing Committee in 2013.

Recently, the Heads of States and Governments at their 4th Council of Europe Summit in Reykjavik in May 2023 recognised "*the urgency of additional efforts to protect the environment, as well as to counter the impact of the triple planetary crisis of pollution, climate change and loss of biodiversity on human rights, democracy and the rule of law*". Climate change and biodiversity loss need to be addressed comprehensively, avoiding to the highest extent possible, exacerbating one for the benefit of the other.

Global Renewable Growth and CO_2 Emissions Mitigation

The expansion of renewables has significantly altered global CO_2 emissions trajectories. Between 2000 and 2024, renewables' share in electricity generation surged from 19% to 40.9% globally, with solar and wind alone contributing 15% (8.1% wind, 6.9% solar) (Brown and Jones, 2024). This growth has curtailed fossil fuel dependency: without clean energy technologies, the rise in global CO_2 emissions over the past five years would have been three times higher (IEA, 2023a). By 2024, renewables avoided approximately 2.6 Gt of annual emissions, equivalent to 7% of global energy-related CO_2 output (IEA, 2024).

Some of the key drivers of emissions reductions are:

- Solar PV: Avoids approximately 1.4 Gt CO_2 annually, equal to the emissions from France, Germany, Italy, and the UK combined (IEA, 2023a).
- Wind: Prevents around 900 Mt CO_2 each year (IEA, 2023a).

- Grid decarbonization: In advanced economies, low-emissions sources (renewables plus nuclear) now exceed 50% of electricity generation (IEA, 2023b).

Despite these gains, global emissions have risen by 1.3 Gt CO_2 since 2019, underscoring the need for accelerated deployment (IEA, 2024). The International Energy Agency (IEA) projects renewables will supply 46% of global electricity by 2030, with solar poised to become the largest renewable source (IEA, 2023b).

European Union: Policy-Driven Leadership

Europe has emerged as a global pioneer in renewable energy, leveraging ambitious targets and innovative policy frameworks to accelerate the decarbonization of its energy system. Through landmark initiatives such as the European Green Deal and the REPowerEU Plan, the European Union (EU) aims not only to address the climate emergency but also to enhance energy security and reduce dependency on fossil fuel imports.

The EU's REPowerEU Plan (European Commission, 2022) seeks to phase out Russian fossil fuel imports by 2027 and substantially increase the share of renewables in its energy mix. The revised 2030 target aims for a minimum of 42.5% renewables in the EU's final energy consumption, with an aspirational goal of reaching 45%, a significant increase from the previous 32% target.

Key measures underpinning this transition include:

- **Solar Energy Strategy:** The EU aims to deploy 600 GW of installed solar photovoltaic (PV) capacity by 2030. Measures include mandatory rooftop solar installations for new public and commercial buildings by 2026 and for all new residential buildings by 2029, as mandated by Article 10 of Directive (EU) 2024/1275 (European Commission, 2022).
- **Wind Energy Acceleration**: To achieve an installed offshore wind capacity of at least 60 GW by 2030 and 300 GW by 2050 (European Commission, COM(2023) 668, 2023), the EU is streamlining permitting procedures and establishing "go-to" areas for renewables, where environmental assessments are simplified.
- **Grid Modernization:** Significant investment is being directed towards modernizing electricity grids to accommodate variable renewable generation and support the electrification of transport and heating. The forthcoming EU Grids Package (Q4 2025) aims to expedite grid permitting, while the planned revision of the EU Strategy on Heating and Cooling (Q1 2026) will deliver additional measures to decarbonize this sector (European Commission, 2024).
- **Promotion of family and industrial self-consumption.** The EU is actively advancing self-consumption of photovoltaic energy across residential and industrial sectors, recognising its critical role in decarbonisation, grid flexibility, and energy sovereignty. Under the European Green Deal, REPowerEU, and RED III, Member States are required to implement streamlined permitting procedures, harmonised grid connection standards, and market-based remuneration schemes for surplus injection.
- **Risk of legislative revision**: The push to accelerate the energy transition and competitiveness could come at the expense of environmental laws, weakening protections for biodiversity.
- **Implementation gaps:** Despite robust environmental legislation at the EU level, the lack of consistent implementation remains one of the most critical bottlenecks. The European Commission's 2025 Environmental Implementation Review reveals that

many Member States still fall short in translating EU directives into effective on-the-ground action. This implementation deficit has far-reaching implications — from escalating environmental degradation and non-compliance costs to eroding the credibility of shared European commitments. The Review quantifies these gaps as a major source of financial and environmental inefficiency, warning that failure to bridge them risks undermining the EU's Green Deal objectives.

Progress to date reflects the effectiveness of this policy-driven approach:

- In 2024, renewables accounted for 46.9% of total EU electricity generation, led by wind (18.3%) and solar (10.5%) (Brown and Jones, 2024).
- Emissions from the power sector fell by 10% year-on-year, largely due to the fossil fuel share in electricity generation dropping to a record-low 28%.
- Member States such as Denmark (88.4% renewable electricity) and Germany (58%) illustrate the feasibility of rapid transitions when ambitious targets are combined with supportive policies.

While the EU is moving in the direction to its 2030 targets, significant obstacles remain:

- **Grid Bottlenecks:** Delays in permitting and the slow pace of infrastructure upgrades could impede the timely integration of new renewable capacity (IEA, 2023b). The Netherlands is a striking example of a country where grid congestion has become a major bottleneck to the energy transition.(https://www.iea.org/commentaries/grid-congestion-is-posing-challenges-for-energy-security-and-transitions)
- **Policy Consistency:** Frequent changes to incentive schemes, such as reductions in rooftop solar tariffs in France, and ongoing regulatory revisions risk undermining investor confidence and delaying project implementation (IEA, 2023a).
- **Market and Investment Barriers:** Despite falling generation costs, low and uncertain profit margins in grid infrastructure discourage private investment. Without stronger public funding, better incentives, or new ownership models, this investment gap could slow deployment and put the EU's climate targets at risk (Christophers, 2024). Complying with environmental legislation (e.g. conducting EIAs) requires sufficient financial, human, and institutional resources. Without adequate public funding and staffing, even strong laws risk being ineffective.

Middle East and Africa: Emerging Potential Amid Constraints

The Middle East and Africa region, historically reliant on hydrocarbons, is gradually pivoting to renewables but faces structural challenges. By 2028, the region aims to add an estimated 62 GW of renewable capacity, with Saudi Arabia accounting for approximately 35% of these additions and the UAE emerging as a regional leader (IEA, 2024). The region benefits from some of the world's highest solar irradiation levels, receiving 22–26% of global solar irradiance, theoretically sufficient to meet up to 50% of global electricity demand (IRENA, 2023a).

However, the starting point remains modest: renewables made up only 5% of electricity generation of Middle East and North Africa in 2024 and are projected to reach just 7% by 2027 (IEA, 2024). Policy frameworks and regulatory structures lag significantly behind those of the EU, resulting in delayed project approvals and underdeveloped supply chains (IRENA, 2023b). Additionally, the region's heavy reliance on oil revenues complicates the energy transition, although the emerging green hydrogen sector offers new opportunities for economic diversification (IEA, 2024).

1.2 Why include biodiversity in renewable energy projects?

Loss of biodiversity is one of the greatest planetary challenges we face today. Destroying biodiversity in the pursuit of renewable energy is not only foolhardy, but also counterproductive and entirely unnecessary. When biodiversity is not properly considered from the early beginning of the project, renewable energy projects can suffer significant delays due to ecological compliance issues, leading to project cost overruns of between 2% and 15%.

Moreover, there are increasing regulatory and legal penalties for failing to protect biodiversity. International agreements such as the United Nations (UN) 2030 Agenda for Sustainable Development, particularly Sustainable Development Goals 14 and 15, highlight the global commitment to protecting life below water and life on land. Similarly, conventions like the Bern Convention, the Convention on the Conservation of Migratory Species of Wild Animals (CMS), and the Kunming-Montreal Global Biodiversity Framework impose clear obligations to conserve species and habitats.

Neglecting biodiversity also means losing essential ecosystem services, including flood protection, carbon sequestration, nutrient cycling, water filtration, and pollination. For example, according to the Integrated Natural Capital Accounting (INCA) project, just ten ecosystem services generated annual benefits worth €234 billion in 2019 for EU countries alone.

Biodiversity considerations can also force site-selection changes, which, together with delays and penalties, can increase a project's Levelized Cost of Energy by 10% to 30%, ultimately eroding financial viability and investor confidence (IRENA, 2023b).

Biodiversity considerations ensuring minimised negative impact on biodiversity and nature contribute to increased public trust towards the developers, planning authorities, and increase support for the renewable energy deployment and the energy transition.

Early integration of robust environmental assessments and biodiversity safeguards is therefore not just a matter of responsible stewardship; it is essential cost management that helps ensure renewable energy projects are truly sustainable for people and the planet.

In addition, the development of renewable energies could be an opportunity to jointly and strategically address the energy transition and nature restoration.

2 Biodiversity conservation concerns: potential conflicts with biodiversity

Besides the positive impact of reducing climate change on wildlife conservation, several negative effects of renewable energies have been shown, particularly on birds and bat populations (Bergström et al., 2014; Conkling et al., 2022; Fleming, 2025; Gómez Catasús et al., 2024). Wind and solar energy may affect birds and bats in many ways, most notably:

2.1 Habitat Loss and Displacement

Habitat loss is one of the significant impacts of solar installations, and to a lesser extent of wind farms, on wildlife (Drewitt and Langston, 2006; Gómez Catasús et al., 2024). The development of these renewable energy sources requires extensive land areas, especially the case of solar energy, often leading to the alteration or destruction of natural habitats. Solar facilities should occupy large open spaces, in urban or highly degraded areas, but they often are situated in open areas that include natural habitats or arable lands. Large-scale photovoltaic arrays can significantly alter the landscape, replacing grasslands, agricultural fields, or even forests, thus removing critical breeding, feeding, and resting habitats (Coppes et al., 2020; Haga et al., 2020). Sometimes they are installed in steppe areas, which may have previously served as essential habitats for various avian species of special conservation concern (Bolonio et al., 2024; Palacín et al., 2023).

The loss of habitat directly reduces the available space for nesting, feeding, and roosting. Birds such as ground-nesting species and bats, which rely on particular habitats for foraging and roosting, experience decreased reproductive success and survival rates. For instance, habitat fragmentation associated with wind farm and solar facility developments can disrupt bird migration routes, forcing birds to seek less optimal habitats, consequently affecting their overall population health and sustainability (Voigt et al., 2024). Large utility solar facilities also cause habitat fragmentation at the landscape scale.

Displacement refers to the phenomenon where birds and bats avoid areas surrounding renewable projects due to perceived threats, noise, or habitat alteration. This effect can significantly impact local biodiversity as certain species are forced to relocate, potentially leading to overcrowding and competition in adjacent habitats and reducing the availability of resources. In wind farms and power lines, direct habitat loss is less significant than avoidance of the habitat caused by presence of high artificial infrastructures, noise or light pollution, especially some sensitive species like some steppe birds. For instance, negative effects of power lines have been detected for key farmland species like the little bustard (*Tetrax tetrax*) and the calandra lark (*Melanocorypha calandra*), both showing displacement up to 1 km (Marques et al., 2025) or the great bustard (*Otis tarda*), with effects on the flight behaviour at least up to a distance of 800 m, perhaps even up to 1,600 m (Raab et al., 2011). Population level impacts have been detected up to 4,5 km from windfarms for species like Dupont's Lark in Spain (Gómez-Catasús et al., 2018).

Bird species sensitive to human disturbance or just to avoid the risk of collision, such as grassland birds and raptors, may permanently abandon traditional habitats in response to the presence of wind turbines (Marques et al., 2021; Tolvanen et al., 2023). Bats may also avoid areas with operational turbines due to noise or electromagnetic interference, leading to reduced foraging success and impaired navigation (Barré et al., 2018; Ellerbrok et al., 2024; Nicholls and Racey, 2009).

The displacement effect can have cascading impacts on ecosystem dynamics, affecting predator-prey relationships and ecological balance. Over time, this can lead to shifts in species distribution and altered community structures, potentially reducing biodiversity in the affected regions.

2.2 Barrier Effects

Barrier effects occur when solar and wind farms obstruct regular migration routes and movement corridors of birds and bats. Wind farms erected along traditional migratory flyways can force birds and bats to take longer, more energy-intensive detours, increasing energy expenditure and potentially affecting survival and reproductive success (Masden et al., 2010b).

Large-scale wind energy projects can act as barriers, especially for migratory bird species like seabirds, geese, cranes, raptors or storks (Masden et al., 2009), and migratory bats (Voigt et al., 2012), disrupting established migration patterns. Similarly, expansive solar farms can deter ground-feeding bird species by presenting an inhospitable barrier due to increased ground temperatures and altered landscapes.

The long-term implications of these barriers include reduced population viability due to increased energetic demands, delays in arrival at breeding or wintering grounds, and potential population isolation leading to genetic bottlenecks.

There can also be cumulative and synergic effects, as multiple small-scale developments may create a large collective impact when considered across a region, further stressing ecosystems and wildlife populations.

Contrary to wind energy or power lines, where negative effects have been described in the last decades, the effects of solar energy remain unexplored. Besides habitat loss or barrier effects, potential impacts to species from solar energy are more variable and site-specific (Gómez Catasús et al., 2024; Lovich and Ennen, 2011).

The novelty and quick spread of this technology require further research to determine the specific effects on each group of animals and their environmental conditions.

2.3 Mortality

Mortality of birds and bats due to collision at wind farms and solar plants is another significant impact (Conkling et al., 2022; Katzner et al., 2025). Turbine blades, which often rotate at high speeds, pose a collision risk, especially during low-visibility conditions or at night (Kerlinger et al., 2010, p. 201). Mortality rates vary widely depending on the location, size, and type of wind turbine (Garvin et al., 2024; Schaub, 2012; Schaub et al., 2024), as well as traits of birds and bats species (Morant et al., 2025; Thaxter et al., 2017).

It seems that bats also suffer barotrauma—an injury caused by rapid pressure changes near the turbine blades—leading to internal haemorrhaging and death (Baerwald et al., 2008). Studies have shown significant bat fatalities, particularly during migration seasons. Birds, especially raptors such as eagles, vultures and hawks, are also vulnerable to collisions due to their hunting behaviour and soaring flight at rotor heights (Balmori-de la Puente and Balmori, 2023; Gauld et al., 2022). Besides raptors, a wide range of bird species collide with turbine blades, including passerines (Nilsson et al., 2023).

On the other hand, wind farms can unintentionally contribute to increased ground-nest predation by attracting more mammalian predators to the area. Landscape features related to wind farm infrastructure, such as roads and clearings, often create favourable conditions for these predators to thrive. As a result, ground-nesting bird populations may face higher predation risks, threatening local biodiversity (Gómez-Catasús et al., 2021).

Solar farms also contribute to avian mortality, albeit at lower rates compared to wind farms. Whereas the evidence that photovoltaic power plants produce are poorly documented, but in the case of concentrated solar power, the flux of solar energy which utilize mirrors to focus sunlight, may kill birds that fly into the area of concentrated sunlight energy (Ho, 2016; Smallwood, 2022).

Power lines also have a significant impact of mortality by collision or electrocution on birds. Data and estimates suggest that mortality caused by power lines is global and of enormous magnitude and given the almost exponential expansion of power lines worldwide in the short and medium term, it can only be expected to increase. Some estimates based on observed data indicate that several million birds could be killed every year in Europe only (Martín Martín et al., 2022). It has recently been found that on the Africa-Eurasia migratory route, almost half of the bird deaths recorded were caused by power lines (Serratosa et al., 2024).

Although it is difficult to quantify the extent of the impact of this mortality on the affected bird populations, numerous studies show that it causes changes in geographical distribution at least on a local scale, making it one of the main factors in the decline of populations and subpopulations of numerous species with conservation problems, as the cases of Bonelli's Eagle (*Aquila fasci*ata), Saker Falcon (*Falco cherrug)* Eastern Imperial Eagle (*Aquila heliaca*) or Great Bustard (*Otis tarda*) in European continent (Martín Martín et al., 2022).

2.4 Cumulative and synergic effects

The environmental consequences of renewable energy infrastructures extend beyond the direct, localised impacts of individual projects. A comprehensive assessment must consider cumulative and synergistic effects, which arise from the aggregation and interaction of multiple stressors over broad spatial and temporal scales (Cook et al., 2025; Masden et al., 2010a). These landscape-level phenomena are critical for understanding the true ecological cost of energy development and for designing effective mitigation strategies.

Cumulative effects are defined as impacts resulting from the incremental changes caused by past, present, and reasonably foreseeable future actions, considered in conjunction with one another (Walker and Johnston, 1999). In this context, the individual impacts previously described—habitat loss, barrier effects, and direct mortality—aggregate across a landscape. For instance, the total mortality pressure on a bird or bat population is not the result of a single wind farm, but the additive sum of collisions from all wind farms, solar facilities, and associated power lines within its range (Arnett and Baerwald, 2013; Masden et al., 2010a). Similarly, the functional habitat loss caused by the disturbance zone around one facility can overlap with that of others, leading to extensive and significant landscape fragmentation that is not apparent when projects are assessed in isolation (Ascensão et al., 2023). The cumulative barrier effect of multiple wind farms can also significantly increase the energetic costs for migratory or commuting species, potentially affecting their fitness and reproductive success (Masden et al., 2010b).

Synergistic effects occur when the interaction between two or more factors produces a combined effect that is greater than the sum of their individual effects (Masden et al., 2010a). A key synergistic mechanism in this context is the interaction between habitat alteration and mortality risk. Habitat fragmentation caused by infrastructure can force birds to alter their flight paths or concentrate their activity in remaining habitat patches, which may increase their exposure to collision risk with turbines or power lines (Conkling et al., 2022; Smith and Dwyer, 2016). Furthermore, these impacts can be amplified by external stressors such as climate change, which alters species' distribution and migration patterns, potentially directing them into regions with a high density of energy infrastructure (Northrup et al., 2019; Ralston et al., 2017).

The scale of these compounding impacts renders project-by-project Environmental Impact Assessment (EIA) insufficient for their management (Canter and Ross, 2010; Therivel and Ross, 2007). Effective mitigation requires a proactive and strategic approach to planning. Tools such as Strategic Environmental Assessment (SEA) are essential, as they operate at the level of policies, plans, and programmes, allowing for the assessment of cumulative effects at a regional or national scale (Fischer and González, 2021). By integrating high-level environmental objectives early in the decision-making process, SEA can guide development towards areas of lower ecological sensitivity, thereby avoiding the most significant cumulative and synergistic impacts before individual projects are even proposed.

3 Objectives of the initiative

The aim of this guidance tool is to facilitate recommendations to the stakeholders for avoiding or minimizing the negative impact of renewable energy facilities on biodiversity, in particular wild birds and bats. This document remarks the relevance of including the perspective of biodiversity conservation from planning and initial design to the decommissioning of renewable energy projects following the mitigation hierarchy to move towards an energy production and transport respectful to nature.

The outcome of the work is to provide practical insight based on existing reliable guidelines and other resources, and show examples inspired by good practice, following the mitigation hierarchy: avoiding, minimizing and mitigating the main risks of solar and wind energy infrastructures for wild birds and bats.

4 Key steps for developing renewable energy projects

This section aims to provide guidance, detailing the recommendations for each step of a new renewable energy project, including some examples of good practices.

4.1 Implementation of the Mitigation Hierarchy as a basic framework

In the design and development of any renewable energy project, it is essential to apply, from the earliest stages, the Mitigation Hierarchy Framework (MHF) (Arlidge et al., 2018; The Biodiversity Consultancy and CSBI, 2015). MHF is a structured approach aimed at minimizing negative impacts on biodiversity throughout the development of the project to address the potential impacts in a structured and effective manner. It involves a sequential set of steps:

- **Avoidance**: The first and most crucial step involves designing projects and selecting sites in ways that completely avoid negative impacts on biodiversity, particularly focusing on areas of high ecological importance.
- **Minimization**: When impacts cannot be completely avoided, steps should be taken to reduce their severity. This may include modifying project designs, implementing best practices, and adopting technologies that lower the impact on wildlife.
- **Mitigation**: This step involves actions taken to offset remaining negative impacts, such as habitat restoration, creation of alternative habitats, and other compensatory measures.
- **Adaptation**: The main objective of adaptive measures is to adjust to or respond to impacts that are already inevitable or cannot be eliminated. Their focus is on addressing the effects or changing conditions to minimize damage or, in some cases, to take advantage of emerging opportunities.
- **Offsetting**: As a last resort, if avoidance, minimization, mitigation and adaptative measures are insufficient, biodiversity offsets are implemented to compensate for residual impacts, ensuring no net loss of biodiversity.

The MHF framework aims to reach a no net loss of biodiversity, which means that habitats and biodiversity should remain in a similar state after the development of the project. This framework is essential for ensuring that renewable energy projects do not aggravate the biodiversity crisis while contributing to sustainable energy production. Applying the mitigation hierarchy not only safeguards biodiversity but also enhances project viability by reducing regulatory, reputational, and financial risks. It aligns with international best practices, such as those outlined by the International Finance Corporation (IFC) Performance Standard 6 and the Convention on

Biological Diversity, making it a critical framework in the responsible development of renewable energy.

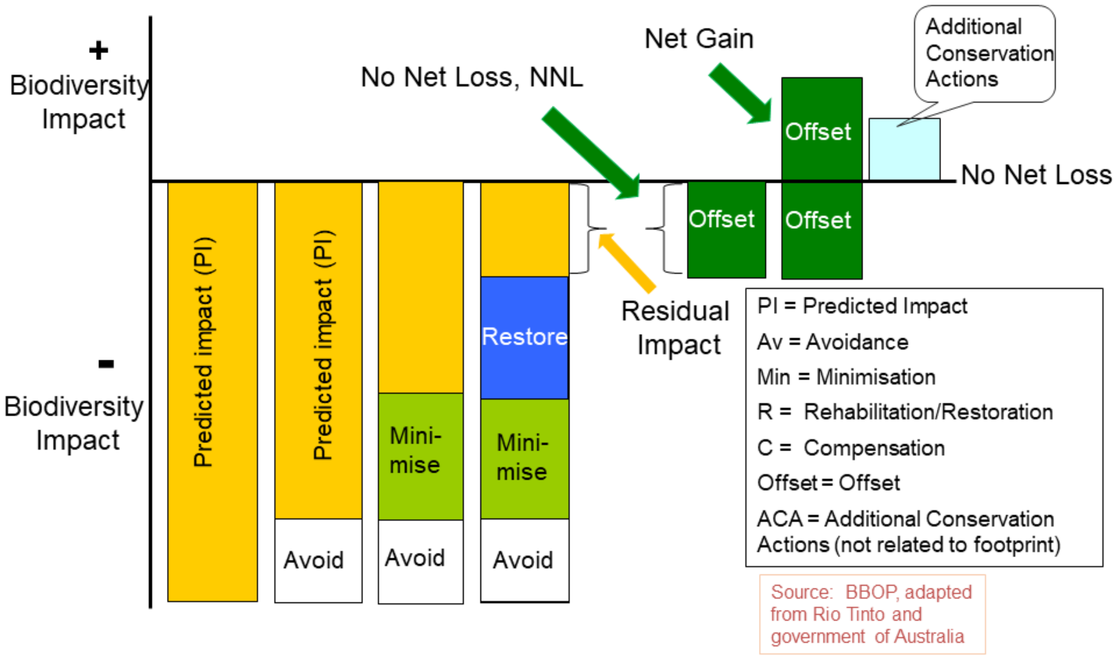


Figure 1. **Mitigation Hierarchy Framework**. Source: BBOP, adapted from Rio Tinto and Australia Government.

4.2 Pre-feasibility and design

Following the mitigation hierarchy procedure, the first step should be to avoid any impact on biodiversity. Therefore, the project design and site selection are necessarily the beginning of a well-planned web of renewable infrastructures. By conducting thorough assessments, developers can identify optimal locations that maximise energy output while minimising ecological impacts.

4.2.1 <u>Site selection</u>

Energy production facilities need some obvious requirements in terms of consistent and strong winds, or solar irradiation and sunlight hours. In addition, several factors constrain these projects and need to be considered:

- **Renewable resources availability:** Evaluating the availability of renewable resources, such as wind and solar energy, is crucial for the viability of any renewable energy project. This assessment can be conducted through on-site evaluations, creating proprietary models, or consulting existing models generated by public administrations or other entities. Proper resource assessment ensures that the chosen site will provide consistent energy output, which is essential for the project's success and long-term sustainability.

- **Electricity grid and accessibility**: proximity and feasibility of previous infrastructure (mainly electrical substation and roads) are crucial issues for the location of renewable energies. As power lines and roads have been demonstrated to severely impact on wildlife, reducing the distance to main roads or transmission lines will decrease the risk of non-natural bird mortality and habitat fragmentation or displacement effects from these types of infrastructures. Because of that, energy production and transport would ideally be planned together to minimise the human impact on biodiversity.

- **Policy constraints**: international and national laws and statements regulate the procedures for implementing renewable energy under their jurisdiction. Detailed and transparent legal limitations promote security for developers to start a project. This includes restrictions associated with endangered or protected species and areas legally designated for biodiversity importance at international, national, regional, or local levels (such as Protected Areas, Natura 2000 sites in Europe, or World Heritage sites). Additionally, areas identified as significant for biodiversity through systematic conservation planning, like Key Biodiversity Areas, Important Marine Mammal Areas, or Wilderness Areas, should be considered and avoided whenever feasible.
- **Local communities**: renewable energy development often competes with long-established land uses and cultural practices, even of general interest. Aesthetic disruption and visual impact of wind and solar farms, light reflection and glare of solar panels, and noise and shadow flickers of wind turbines prompt local complaints and must be within regulatory limits. Moreover, a negative attitude of local people to renewable energies strongly obstructs the rent or acquisition of lands for these projects.
- **Land cover and use**: habitat loss is inherent to any type of energy production, even in renewable energies, so it is preferable to use degraded habitats, industrial areas, or highly altered habitats. Prioritise degraded, brownfield and rooftop-PV sites ("land sparing"), avoiding seminatural and agricultural steppe areas important for threatened birds is especially important. For this purpose, satellite images and derived products, before proper site prospection, are an inexpensive approach. Public products such as Corine Land Cover in Europe or Copernicus in other countries are recommended to be included in pre-feasibility phases.
- **Weather conditions**: Apart from the potential impact on energy production, the weather is a key factor in determining collision risk. Foggy or windy weather may increase bird collisions with power lines or wind turbines, as these conditions limit visibility and manoeuvrability.

In addition, some countries have recently introduced the ecological **non-price criteria** in their auctions for renewable energy development. These competitive bidding processes consist of evaluating factors beyond just the lowest bid, including environmental sustainability, biodiversity conservation, or habitat restoration. In this case, developers need to have in mind measures and actions to meet specific environmental requirements.

These criteria aim to deliver projects that are not only cost-effective but also offer long-term value to society and the environment by reducing negative impacts on biodiversity.

4.2.2 Screening

In this sense, sensitivity mapping appears as an anticipatory, integrative, and inclusive tool for aiding planning and biodiversity conservation. Sensitivity mapping set a common basic framework and help developers in several ways: i) Easily identify appropriate project site options, including no-go areas, ii) reduce potential conflict with and demands from conservation stakeholders, iii) facilitate comprehension of regulatory conditions and access to finance, and iv) reduce costs in early stages of the project and the potential offset measures.

A huge variety of approaches for sensitivity mapping has been developed by governments and NGOs around the globe. Although each organisation uses its own available information and expert criteria, some elements are quite common in the elaboration of these maps. We bring here some of them:

- **Scale**: Sensitivity maps are usually part of strategic planning decisions. Therefore, they operate at a landscape scale, often regional, national, or multinational scale. Because of that, they are usually promoted by governments and should not replace the local screening or baseline studies for site-specific Appropriate Assessment.
- **Resolution**: biodiversity data and other relevant environmental information resolution are usually in low resolution (1 km2 or even more).
- **Protected areas**: renewables projects should be located outside of protected areas from category Ia, Ib and II from the IUCN Guideline (Stolton et al., 2008) and European Diploma areas. Even more, a buffer of 1 km from these protected sites is recommended. Baseline studies should collect further information and evaluate the potential impact on the species that motivate the designation of N2000 or Emerald areas at further distances.
- **Other areas of interest**: areas with large concentrations of birds, such as migration crossing points or stop-overs (RAMSAR sites) IBA or Ramsar sites are also important, even if they do not have legal implications. Although sensitivity maps from governments rarely contain information about anthropogenic food resources such as landfills or fisheries, including a buffer from these facilities is strongly recommended, as they attract hundreds and thousands of birds.
- Compile **biodiversity information**: during sensitivity mapping development, biodiversity distribution and relevant habitats and areas must be included. At a minimum, the following information is recommended:
  - Distributional dataset: often, local or national governments have information about the distribution of birds in national atlas. Moreover, NGOs and research centres have spatially explicit information on animal distributions. High species richness (e.g. the fourth quartile) or the presence of endangered species motivates the designation of a sensitive area in the map.

  - Migration: sensitivity mapping should include information about when and where the main passages of migrant birds are placed. Migrant corridors like Gibraltar Stretch or sites like wetlands in Morocco concentrate thousands of migratory birds for several months. Locating and signalling staging areas, stopover sites, and ‘bottleneck’ areas should be considered in sensitivity mapping.

  - Roosting and nesting sites: Most birds are central place foragers during the breeding season as they need to return to their nest to feed the nestlings. This biological condition restricts their movement to search for food during the breeding season. Setting a distance buffer from nests equivalent to the most common range of movements or the median daily recovered distance of endangered or relevant species assures food availability and the continuity of the breeding pair. In this sense, nearby areas of colonial breeding birds (vultures or marine birds) are particularly relevant in offshore and onshore wind farms.

- **Scoring system**: experts have suggested several scores to evaluate the potential threats of renewable energies to biodiversity. These scoring systems include biological traits (wingspan loading, migratory behaviour), behavioural traits, and conservation status (D'Amico et al., 2019; Gauld et al., 2022; José C. Noguera et al., 2010; Refoyo Román et al., 2020).

Minimum requirements in a sensitivity map:

- Species that motivated the sensitivity map.
- Protected areas and their level or degree of protection.
- Well-known Biodiversity Hotspots, such as: straits, RAMSAR sites, and landfills.

Nonetheless, a successful sensitivity mapping should be a collaborative process based on the best knowledge available, whenever it is possible. Local and regional governments, NGOs, stakeholders, and the public should have the opportunity to explain their point of view and provide their contribution.

BOX 1: Flying corridors, sensitivity map of transmission power lines of Spain

Between 2010 and 2016 Red Eléctrica developed the project "Identification, Characterization, and Mapping of Bird Flight Corridors Interacting with High-Voltage Power Lines", later updated in 2021.

The core objective of the project is to cartographically delineate the flight corridors of species particularly sensitive to collisions. This enables the identification of high-risk areas, serving as a basis for decisions related to the layout of new power lines, seeking routes of minimal environmental impact, as well as for prioritizing corrective actions such as the installation of anti-collision devices on existing lines. The scope of the project covers the entire Spanish territory, producing geographic information systems (GIS) for each of the 17 autonomous communities, all of which are integrated into a comprehensive national GIS platform.

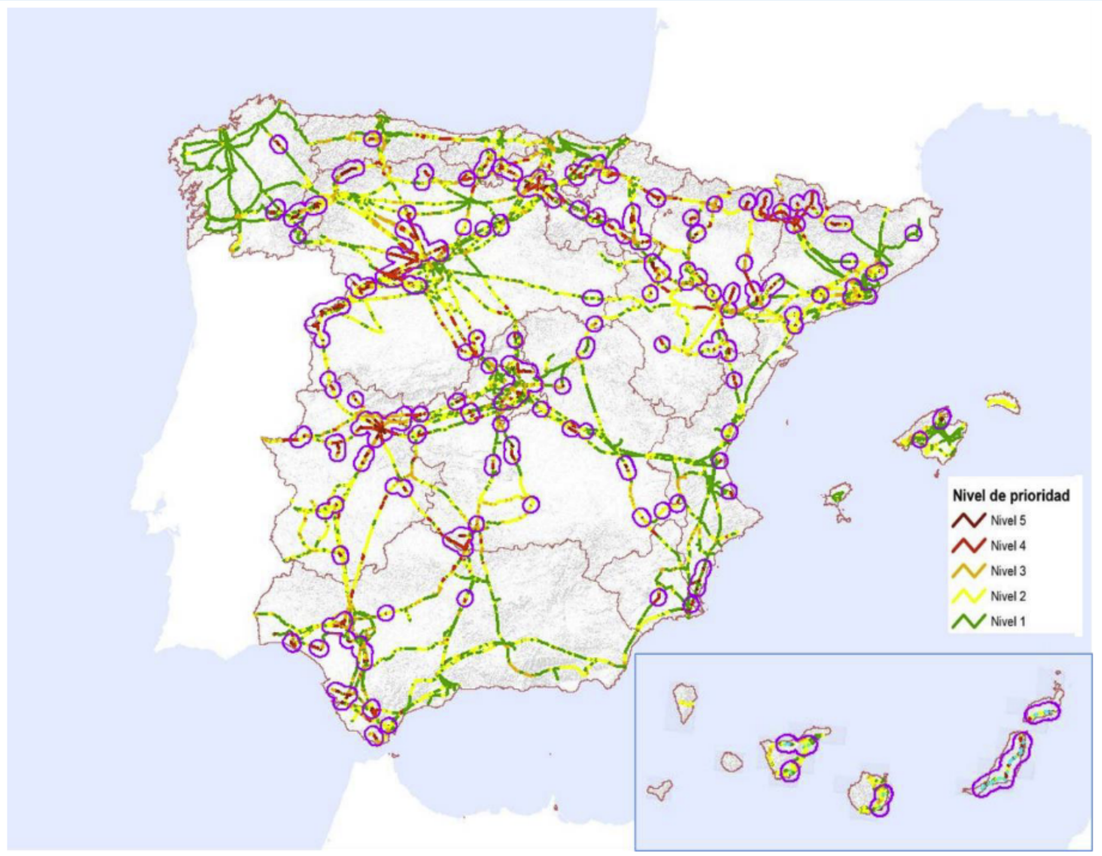
Focal species were chosen based on their documented or likely interaction with electric lines, gregarious behaviour, predictable movement patterns, and conservation status. The list includes 52 species: steppe birds (e.g., Great Bustard, Little Bustard), scavengers (e.g., Griffon Vulture, Bearded Vulture), raptors (e.g., Spanish Imperial Eagle), waders, aquatic birds, and endemic species vulnerable to infrastructure-related impacts.

The project outputs are structured into three main tools. The first is the GIS itself, which compiles environmental and avian data for each region based on raw observational inputs. The caution level provides finer-scale (1x1 km UTM) grids highlighting potentially sensitive zones based on species-specific vulnerability criteria. Additionally, the GIS incorporates information on known flight paths and corridors, zones that are regularly overflown by birds, often at high altitudes, where the collision risk is generally lower.

The second tool developed by the project is a set of sensitivity maps based on the spatial distribution and aggregation patterns of 52 focal bird species. These maps are constructed from the caution-level data, with each species weighted according to a sensitivity coefficient calculated from biological, behavioural, and conservation-related factors, such as flight behaviour, morphology, and threat status. Advanced spatial analyses are used to identify high, medium, or low sensitivity zones. High-sensitivity areas are characterized by significant concentrations of focal species, while medium-sensitivity zones contain species without strong aggregation. Low-sensitivity zones lack focal species presence altogether.

The third component consists of collision risk maps, designed to guide the prioritization of corrective actions along power lines. These maps combine sensitivity data with additional spatial factors known to increase collision likelihood. Such factors include bird attractors (landfills, wetlands), terrain features that funnel bird flight paths (valleys, river corridors), climatic conditions like frequent fog, and the presence of other high-risk infrastructure such as wind farms. Historical collision records are also considered. The resulting risk index is calculated at the 1x1 km grid level and enables the assessment of risk for individual line segments by superimposing the transmission network over the risk matrix. This facilitates the identification of the most dangerous spans, allowing resources to be directed efficiently toward areas where corrective measures would have the greatest impact on bird conservation.

Redeia has made the mapping available to the different regional governments. It is also the tool that guides its annual marking plan, with the plan being to complete the mark of all the spans considered critical by 2025.



Source: https://www.redeia.com/es/proyecto/aves-y-lineas-electricas-cartografia-de-corredores-de-vuelo.

4.3 Pre-construction

The initial planning stage of a renewable energy project is not only a technical requirement but a decisive moment to align development goals with ecological integrity. During this stage, evaluating project alternatives within the previously identified priority areas is critical. These alternatives must be designed to avoid significant ecological conflicts, minimize residual environmental effects, and avoid placing protected species and habitats at risk. This selection process should be proactive and context-sensitive, focusing on locations where adverse impacts can be effectively mitigated or entirely avoided.

The primary objective of this stage is to refine project design in a way that the remaining environmental impacts fall within a manageable threshold, enabling the responsible environmental authority to issue a favourable Environmental Impact Statement (EIS). A well-structured assessment aligned with the legal frameworks of the respective jurisdiction increases procedural efficiency and significantly reduces the risk of rejection or delay.

In this stage, Environmental Impact Assessment (EIAs) are more than a regulatory requirement. When properly implemented, they are tools for designing better, more resilient, and more widely accepted projects. For renewable energy to deliver on its promise of sustainable transformation, it must integrate the principles of biodiversity protection, social equity, and long-term ecological viability from the very beginning.

4.3.1 Baseline studies (Scoping and Impact Analysis)

Understanding the environmental baseline conditions is essential to predicting, evaluating, and ultimately managing the ecological impacts of renewable energy development. Once a potential site is selected, the scope of assessment must narrow from the regional level to the local scale through detailed ecological fieldwork. This stage requires gathering robust, site-specific data on species presence, abundance, seasonal behaviours, and habitat characteristics. The main objectives at this stage are:

- Identify the key species in the area, depending on the relevance of that species (scarcity, conservation status, high percentage of the global population at the local site) and the impact of the renewable energy facility.
- Establish the number and abundance of the species in the area.
- Determine the potential effects of renewable energies on biodiversity.

Particular attention must be paid to identifying the key or target species, as this may determine the site selection with potential consequences for other species. The criteria to determine key species are usually based on abundance, conservation status and their sensitivity or vulnerability to the renewable energy elements. Sensitivity refers to the susceptibility of a species to a particular threat based on its intrinsic traits. On the other hand, vulnerability considers both sensitivity and exposure to the impact. So, vulnerability is a measure of how likely a population will be affected by a renewable energy project in a particular context (location, mitigation and conservation measures, or other threats acting together at the same time).

There are a lot of guidelines about these topics that are fully developed in section 4.

In the context of renewable energies, certain orders or groups of species have been identified with higher sensitivity to each type of energetic facility:

	Power lines	**On-shore wind energy**	**Off-shore wind energy**	**Solar energy**
Steppe birds	Mortality (collision) and displacement	Mortality and displacement		Habitat loss and connectivity
Raptors	Mortality (collision and electrocution)	Mortality and displacement		
Marine birds	Mortality (collision)		Mortality and displacement	
Water birds	Mortality (collision)	Mortality		Mortality (only at CSP facilities)
Bats		Mortality		Habitat loss and connectivity

Once key or target species have been identified through baseline assessments, the subsequent research phase must shift toward a more intensive and temporally nuanced investigation. Understanding species' ecological dynamics across different times of the year is essential, as the distribution, abundance, and vulnerability of wildlife often vary significantly between breeding, migratory, and overwintering periods. Therefore, field studies must be extended across multiple seasons to capture temporal variations in behaviour, habitat use, and population dynamics. Failing to consider these seasonal patterns can lead to underestimating critical risks or overlooking periods of heightened sensitivity, such as breeding or stopover phases during migration.

In particular cases, the deployment of advanced tracking technologies is strongly recommended to document these temporal ecological patterns accurately. GPS telemetry and radio-tagging devices provide high-resolution movement data, allowing researchers to determine daily and seasonal activity ranges, detect nesting and foraging sites, and delineate migration corridors. However, the stress and capture of animals involve some risks, especially for protected species. Therefore, these datasets are invaluable not only for their capacity to understand species' ecology but also for their impact on animals, and their information must be shared whenever it is possible.

Complementing these techniques, spatial modelling methods such as connectivity analysis and kernel density estimation enable the visualization and quantification of habitat use intensity and movement pathways. Connectivity models help anticipate how the placement of solar arrays or access roads might disrupt animal movement, sever ecological corridors, or isolate habitat patches. Kernel density estimation allows for the creation of heat maps indicating areas of concentrated use, which can inform both micro-siting decisions and mitigation design.

Beyond species-specific considerations, it is equally important to evaluate landscape-level features that inherently pose high biodiversity risks. Wetlands, for example, serve as crucial stopover points and foraging grounds for migratory birds; landfills can attract large numbers of scavenger species, increasing collision risk near energy infrastructure; and caves represent essential roosting habitats for many bat species. Each of these features can act as ecological attractors and must be factored into project design with appropriate spatial buffers.

Integrating these high-resolution data layers—species movements, habitat preferences, and critical risk zones—into project planning creates a robust decision-making framework. It allows developers and regulators to anticipate and reduce negative impacts before they occur, making the environmental assessment not only a reactive tool but a strategic planning instrument that enhances both conservation outcomes and project viability.

General recommendations for baseline studies:

- All methodologies should follow international standards and be seasonally timed to coincide with the biological activity of the target species.
- Performed by qualified professionals with expertise in field ecology, data analysis, and environmental law should lead these studies.
- At least 1 year of field studies to cover the annual life cycle variations: movements, population shifts, animals´ detectability, and other human perturbations to wildlife.
- Use technology as needed for the project, such as passive acoustic monitoring, camera traps, GPS tracking, or other emerging tools for detailed studies of specific species or wildlife groups.

- Advanced geostatistical methods—such as home range studies, species distribution models, connectivity analysis, mortality risk models, or population viability analysis—should be required to identify key areas and accurately assess project impacts.
- Mapping of high-risk spots: setting a buffer of 5 km from landfills and main wetlands, and a buffer of 1 km from cave openings is recommended.

> BOX 2: Homogenizing baseline studies methodologies
>
> Disentangling the biodiversity richness in certain areas could be a challenge. Nocturnal species, such as bats or owls, are more difficult to detect and require specific methodologies and techniques. Given the unfavourable conditions for visual identification in the high activity period of these species, experts have studied their sounds.
>
> Passive Acoustic Monitoring (PAM) is a non-invasive technique that relies on recording and analysing the sounds of animals. This methodology has been shown as a key tool for studying biodiversity and soundscapes around the globe. However, there is still limited knowledge of its specific applications in ecoacoustics, particularly regarding the taxonomic groups studied, the habitats analysed, the types of recorders used, and the analytical methodologies employed.
>
> The Spanish Research Network on Ecoacoustics (REIE, by its acronym in Spanish) is a group of scientists and technicians that have promoted the standardization of sampling protocols, acoustic data storage and processing practices, tagging processes, and metadata documentation. To compare and evaluate site sitting projects, a uniform and standardized methodology is necessary.
>
> **Source:** III SIBECOL & AEET meeting (2025)

4.3.2 Impact assessment

The impact assessment stage aims to quantify the direct, indirect, and cumulative effects of the solar project before construction begins. This step is very important, as its ultimate goal is to design the most appropriate mitigation, adaptation and compensatory measures to be implemented in the following steps.

Birds and bats are often focal groups, given their demonstrated sensitivity to renewable energy infrastructures. As the impacts of renewable energies on birds and bats were described in section 2 of this document, here we focus on the methodologies to evaluate these negative effects.

In renewable energy developments, the risk of adverse impacts on bird populations is multifaceted and must be carefully assessed through both direct and indirect pathways. Among the most immediate concerns is the risk of collision to wind turbines, power lines or CSP. The aim of collision risk models is to estimate the likelihood of birds striking infrastructure by integrating species-specific flight behaviours, visibility factors, weather conditions, or landscape context. While absolute mortality figures are difficult to predict without long-term empirical data, these models provide comparative risk levels that can help identify the most hazardous design elements or locations.

The integration of telemetry data, such as GPS tracking and radio telemetry, can enhance the predictive power of these models. Tracking technologies allow researchers to map detailed flight paths, roosting sites, and foraging areas. In wind energy projects, for instance, telemetry has revealed that even minor deviations in turbine placement can significantly reduce exposure of migrating raptors or soaring birds. In solar projects, telemetry data can detect behavioural changes such as habitat avoidance or increased flight distances, indicating a displacement effect caused by panel glare, fencing, or human activity. Similarly, in areas with extensive transmission lines, tracked individuals may alter their routes or reduce site fidelity due to perceived collision risk or obstruction of visual landmarks. These behavioural responses, while less immediately visible than physical mortality, can accumulate over time, reducing energy efficiency, breeding success, or territory stability.

Alongside direct mortality, indirect impacts such as food web disruption must also be assessed. Raptors and other predatory birds are especially vulnerable to declines in prey abundance resulting from land-use changes linked to energy infrastructure. In solar plants or wind farms, land clearing, soil compaction, and changes in vegetation structure can reduce populations of small mammals, insects, and other prey species. To assess these indirect impacts, practitioners should implement field-based prey availability studies, using standardised techniques such as line transects, trapping grids, or regurgitated pellet analysis at key foraging zones.

To translate these effects into population-level risk estimates, population viability analysis (PVA) provides a powerful modelling approach. PVA integrates species-specific demographic data, such as survival rates, fecundity, and dispersal, to simulate future population trajectories under different impact scenarios. This is especially valuable when assessing whether a project may cause localized extirpation, reduce genetic diversity, or create a demographic sink in which mortality consistently exceeds reproduction. Sink effects are of particular concern in landscapes already under pressure from multiple infrastructure projects, where cumulative impacts may compound the effect of each additional development.

Understanding where the thresholds of irreversible ecological change lie is central to defining the limits of acceptable impact. For example, a minor reduction in prey density or a small increase in collision mortality may seem negligible in isolation, but once compounded with other stressors, may tip a local population into decline. Defining these ecological thresholds, however, is a complex and often politically sensitive task. It typically requires formal guidance from regulatory authorities or scientific panels and must be grounded in both ecological evidence and societal values. While environmental practitioners can model risk and estimate likely outcomes, the authority to determine what constitutes a “significant” or “unacceptable” impact generally rests with governments or mandated institutions. Their role is to set thresholds through law, policy, or regulatory standards, informed by transparent, science-based assessments delivered during the Environmental Impact Assessment process.

As bats are much more difficult to observe than birds, the use of acoustic detectors to record species activity is essential. Recent studies have shown the relevance of the strategic placement of such devices and the identification of roosting habitats, including caves and forest structures. In some cases, specially trained dogs can assist in locating bat colonies in dense vegetation. Recommendations currently advise avoiding any development near major roosting sites. Structured forests and riparian areas, frequently used by bats for foraging, should also be excluded from development areas whenever possible.

General recommendations for assessing impacts on birds:

- Collision risk models to estimate mortality (only wind farms).

- Use the available information from radiotelemetry and GPS devices to evaluate effects on habitat use. These devices not only show migratory routes, but they also allow us to estimate the home range areas and specific habitat use from local populations.
- If new projects include nearby areas surrounding raptors´ nests: prey availability studies to determine the potential impact on the productivity and viability of raptors should be mandatory.
- When baseline studies or environmental impact assessment indicate potential mortality for target or key species, population monitoring to estimate the impact at the population level (risk of local extinction, sink effect, etc.) must be applied.

General recommendations for assessing impacts on bats:

- Bat detectors: place the bat detectors at different heights in the wind masts if possible (Roemer et al., 2017). One recorder per five wind turbines within an area defined by a radius of at least 1 km around the wind turbine envelope, in favourable habitats or at least one recorder for every 50 hectares or for each polygon occupied by the project that is more than 100 meters from other polygons, ensuring that all present habitats are covered.
- For windfarm projects, it is crucial to evaluate the phenology and daily activity patterns of bats, and monitor temperature and wind conditions.
- Searching for bat refugees: caves and forests. The use of dogs to detect bat colonies in forests.
- At least 500 meters from small colonies and 5 km from large colonies or roosting places (more than 100 bats) (Voigt et al., 2024).
- Avoid highly structured forests and water areas as they are communal roosting and foraging places for bats (Voigt et al., 2024). For windfarms, it is recommended to place windmills at least 100-200 m away from forests and other habitats of interest for bats (Rodrigues et al., 2015).
- Use of a standardized framework improves comparability and reproducibility, following the minimum key parameters (Asmus et al., 2025). Reporting of equipment and methods, even more providing raw data, would promote more robust bat monitoring and acoustic research, which is essential for improving transparency across studies.

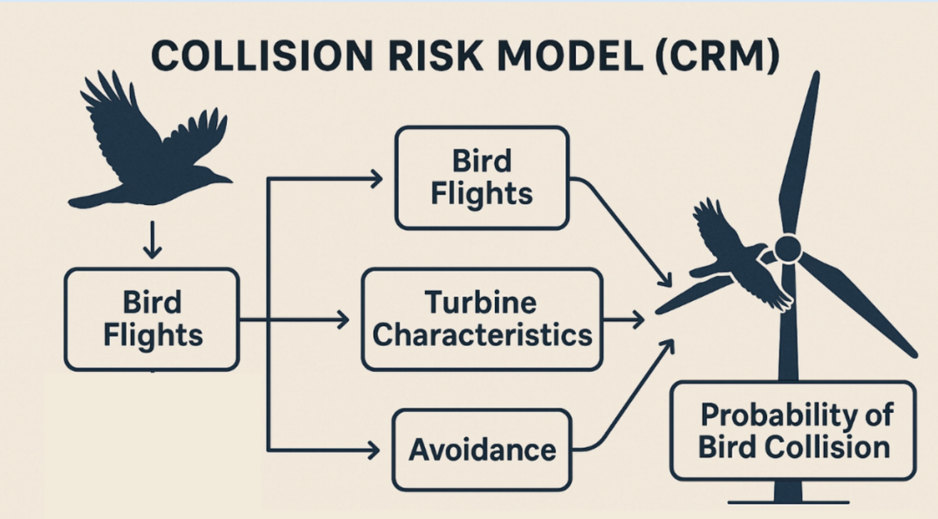
BOX 3: Collision Risk Modelling in Scotland

The Scottish Natural Heritage (now NatureScot) has incorporated a modelling framework known as the Collision Risk Model (CRM) developed by Band and colleagues in 2012 to estimate the likelihood of birds colliding with wind turbine blades. Updated through successive years, with the latest guidance released in 2024, the CRM provides a structured method for quantifying collision risk, offering a tool that balances precision with feasibility. The model was designed to support environmental assessments in the planning stages of wind energy development, helping decision-makers evaluate and mitigate impacts on bird populations.
At the core of the CRM is a three-stage process. The first stage estimates the number of bird flights intersecting the rotor-swept area of a proposed wind farm, based on observational data from vantage point surveys. These observations, which record flight duration, direction, and height, are scaled up to provide annualised estimates of how often birds might enter the turbine risk zone.

The second stage calculates the probability that a bird passing through this rotor area will collide with the wind turbine. This probability is derived from a detailed spreadsheet model that incorporates bird biometrics—such as wingspan, body length, and flight speed—alongside turbine characteristics. The outcome of this stage reflects a worst-case scenario in which birds do not detect or avoid turbines.

To reflect more realistic outcomes, the third stage applies an avoidance rate. This is a correction factor representing the proportion of birds that successfully evade the turbines. This correction is based on expert criteria or empirical evidence, depending on the available information. The combination of transit frequency, strike probability, and avoidance correction yields a final estimate of potential fatalities, typically expressed as annual figures per species. The model's standardised spreadsheet tool enables consistency across environmental impact assessments, making it possible to compare risks between projects or assess cumulative impacts.

The model has become a regulatory cornerstone in the UK and Ireland, referenced in environmental statements and integrated into licensing decisions. Its enduring relevance lies in its balance of biological rigour, methodological transparency, and adaptability to ongoing ornithological research. As wind energy expands into new regions and turbine designs evolve, NatureScot continues to refine the CRM, ensuring that renewable energy development proceeds with due care for avian conservation.



Source: https://www.nature.scot/doc/guidance-using-updated-collision-risk-model-assess-bird-collision-risk-onshore-wind-farms

4.3.3 Early and effective public participation

Public engagement should not be an afterthought. Environmental assessment procedures must incorporate public participation from the earliest conceptual phases of the project. Informing the public at the scoping stage and organising participation events provides a foundation for building trust, addressing concerns, and incorporating local knowledge into project design.

Meaningful, early participation ensures better decisions and reduces conflict. Weak or superficial consultation practices, on the other hand, often lead to public resistance, legal challenges, and reputational damage. Poor public consultation practices foment NIMBYsm (for not in my backyard) as local communities feel excluded, circumvented and ignored. International commitments such as the Aarhus Convention underscore the right of citizens to participate in environmental decision-making. Governments and developers must embrace this not only as a legal obligation but as an opportunity for co-creation.

An instructive example comes from Slovenia, where the national spatial plan was developed through a highly participatory Strategic Environmental Assessment (SEA) process. With the active involvement of BirdLife's partner DOPPS, the government succeeded in embedding environmental priorities and stakeholder views into territorial planning. This transparent and inclusive process reduced legal conflict, built legitimacy, and improved environmental outcomes.

BOX 4: The Dialogue Forum on Renewable Energies and Nature Conservation

The Dialogue Forum on Renewable Energies and Nature Conservation is an ongoing strategic partnership between NABU and BUND Baden-Württemberg, jointly funded by the Ministry for the Environment, Climate and Energy of Baden-Württemberg. Established in 2012 and extended through 2024, the Forum provides an institutionalised platform to reconcile the state's ambitious renewable energy expansion with binding conservation objectives, ensuring that large-scale decarbonisation does not undermine ecosystem integrity or species protection.

At its core, the Forum employs a multi-stakeholder, participatory approach, engaging a broad constituency of actors, including environmental NGOs, grid operators, local and regional authorities, planning consultancies, research institutions, and affected communities. Through structured dialogue formats, thematic working groups, and conflict-mediation workshops, the initiative facilitates evidence-based consensus-building on how to integrate biodiversity safeguards throughout all phases of energy infrastructure development. Emphasis is placed on compliance with the EU Birds and Habitats Directives, the Federal Nature Conservation Act, and the Baden-Württemberg Climate Protection and Climate Change Adaptation Act.

A critical component is the Forum's role as a technical advisory hub. By producing practical guidance documents, species-specific assessment protocols, and mitigation toolkits, it enables project developers to anticipate and minimise ecological conflicts during site selection and permitting procedures. This early integration of ecological due diligence—e.g., habitat mapping, ornithological surveys, and corridor connectivity assessments—has been shown to significantly reduce procedural delays and the risk of legal challenges during construction phases.

In the domain of grid and corridor management, the Forum promotes ecological maintenance strategies for transmission and distribution lines, drawing on best-practice frameworks such as habitat-compatible clearance techniques and the creation of biodiversity corridors beneath overhead lines. This approach seeks to transform potential linear barriers into multifunctional green infrastructure, thereby enhancing landscape connectivity for priority species while ensuring operational safety standards are upheld.

The Forum's thematic scope encompasses multiple renewable energy vectors. In onshore wind development, it convenes technical roundtables to align turbine siting with bat and raptor protection and generates position papers that balance species action plans with climate targets. In the solar energy sector, the Forum provides guidelines on ecologically compatible design of ground-mounted PV systems, addressing soil sealing, pollinator habitats, and long-term vegetation management. For grid expansion, it disseminates state-of-the-art practices for bird deflectors, soil conservation during trenching, and conflict-sensitive routing in Natura 2000 sites.

Cumulatively, the Dialogue Forum has become an essential governance mechanism for mainstreaming nature-positive solutions within the renewable energy transition in Baden-Württemberg. Its outputs—including comprehensive knowledge briefs, stakeholder manuals, and regionally adapted policy recommendations—serve as benchmarks for other federal states seeking to operationalise the "climate and nature protection hand in hand" principle.

Source: https://www.dialogforum-energie-natur.de/

4.4 Construction

4.4.1 Implementation of mitigation and adaptive measures

Once an impact has been detected, actions have to be performed to minimise negative effects on biodiversity through the implementation of measures design in the evaluation step. The main priority in any mitigation strategy is to prevent ecological impacts altogether, always based on the best available knowledge. It must take into account the differences between the impacts of construction and operational phases, as some impacts only affect one of them, while others affect both.

When total avoidance is not feasible, the focus must shift to minimizing the magnitude, duration, and spatial extent of the anticipated impacts. This involves adjusting project design and operational parameters to reduce impact without compromising technical performance. In renewable energy developments, mitigation may include reducing the number of wind turbines or the extension of the solar facilities or power lines. However, longer power lines or higher extension of solar facilities could mitigate the impact on biodiversity, if these changes allow to incorporate the biodiversity perspective in the project, such as margins of natural vegetation or avoiding the breeding area of a key raptor species.

Mitigation must also consider timing, not just placement. Scheduling construction activities to avoid biologically sensitive windows can significantly reduce the disturbance impact of otherwise necessary activities. This requires close coordination between developers and ecological experts and should be informed by species-specific life cycle data and local ecological knowledge. As there is a high variability of patterns of activity between species and among different latitudes, the scheduling of works should be adapted for the key identified species in the area.

A frequently overlooked but critical component of mitigation planning is the evaluation of effectiveness. It is not enough to implement a mitigation measure; it must be assessed in practice to ensure it functions as intended under real environmental conditions. Integrating pilot trials into the planning and implementation phases can help test new approaches and refine best practices.

Mitigation is not a static obligation; it should be treated as a dynamic, adaptive process. Measures must be monitored, reviewed, and—where necessary—modified in response to new data, unexpected outcomes, or changing environmental conditions (Northrup and Wittemyer, 2013). This approach not only improves ecological outcomes over time but also contributes to building a practical knowledge base that benefits future projects, regulators, and scientific institutions.

Ultimately, mitigation is most effective when it is anticipatory rather than reactive, designed with a clear understanding of local biodiversity, supported by empirical evidence, and executed with precision. When done well, mitigation reduces environmental risk, fosters public confidence, and demonstrates that renewable energy development and biodiversity conservation are not mutually exclusive goals but can be achieved in tandem through intelligent, science-driven planning.

General recommendations:

- Strategic Planning and Siting: The primary mitigation measure involves strategic site selection on low ecological value land, such as degraded areas or low-yield agricultural fields, while strictly avoiding protected zones. Project design focuses on minimizing the physical footprint and consolidating infrastructure to reduce cumulative impacts. This proactive approach ensures that ecosystem disruption is avoided from the project's inception.
- Scheduling to minimise disturbances: agreeing with developers on the timeline of works according to the phenology of birds or bats is a low-cost and effective measure to avoid unnecessary disturbance. Some general recommendations can be made:
    - Avoiding work in the nearby nesting areas during pre-incubation to fledgling time.
    - Restrict the traffic road and works to non-important migratory stopover areas.
    - Mandatory nesting place removals from power lines outside the reproductive period of the species.
- Establishment of regular monitoring programs to assess the condition and effectiveness of the implemented measures.

Recommendations for power lines:

- Installation of anti-collision devices on power lines identified as potentially dangerous through prior assessment, considering the possibility of undergrounding the most problematic sections during the project planning phase.
- Use of approved, weather-resistant anti-collision devices; choice of the most suitable designs according to these conditions and the sensitive species present based on the Environmental Impact Assessment.
- Prioritise the use of mobile and reflective anti-collision devices,
- Election of bird-safe designs and/or insulated crossarms on poles for all new distribution lines to minimise the risk of electrocution.
- Installation of insulating elements on dangerous supports where the design of the crossarm and materials is not sufficient to ensure safety (mainly special supports: switching supports, supports with transformers, derivation supports, etc.), at least in the most sensitive areas.
- Use insulating elements with approved designs and materials that ensure their effectiveness and durability.

- Ensure the correct installation of insulating devices by training installers and supervising technicians.
- As a general rule, safe designs and insulation should take precedence over anti-perching devices. These latter should only be used on pylons where the presence of birds compromises the safety of the power line, and bird-safe, species-specific designs should be chosen.
  - Avoiding the use of anti-perching and anti-nidification devices whose effectiveness, safety and durability are not proven.

Recommendations for wind farms:

- Incorporating systems of Shutdown of Demand (SDoD) to reduce the risk of bird-turbine collisions.
- Operational curtailment is a highly effective, targeted mitigation measure. It involves elevating the turbine's standard cut-in speed, typically to a threshold of 5.0 or 6.0 m/s, exclusively during pre-defined periods of high bat activity (e.g., nights with low wind and warm temperatures during migration season). Since the majority of bat fatalities are documented at lower wind speeds, this approach directly addresses the highest-risk conditions. This method significantly reduces bat mortality while often resulting in only a marginal loss of annual energy production, making it a cost-effective conservation solution.
- Acoustic deterrence systems are employed to reduce collision risk by actively repelling fauna from the rotor-swept zone. For bats, nacelle-mounted ultrasonic devices emit high-frequency sound, creating an acoustic field that jams their echolocation and discourages approach. For avifauna, targeted bioacoustic systems broadcast species-specific distress or alarm calls upon detection, prompting an avoidance reaction. These technologies aim to create an auditory buffer around turbines, thereby minimizing harmful interactions with wildlife.
- Demand-controlled obstacle lighting (ADLS) such as Parasol solution (https://www.parasolsystem.com/). This system maintains turbine obstruction lights in a default off-state, activating them via radar only upon the detection of an approaching aircraft. This on-demand operation significantly mitigates light pollution and reduces the fatal attraction and disturbance to local fauna, particularly avifauna and bats.
- Painting of blades: beside it is a controversial measure, certain painting patterns seem to reduce the number of collisions of birds (May et al., 2020). More studies are necessary to confirm the best pattern and the species or group of species that react to this measure.
- Habitat Management: This involves land cover manipulation to discourage the proliferation of prey species or attractive habitats for wildlife. Actions include avoiding crops that attract small mammals or granivorous birds and managing key prey populations, such as rabbits, to make the area less appealing for foraging raptors.
- Systematic Carcass Removal: A rigorous program is implemented for the regular surveillance and prompt removal of any animal carcasses. In regions with extensive livestock farming, this is critically supported by formal agreements with local ranchers to ensure the immediate reporting and removal of livestock mortalities, thereby preventing the site from becoming a reliable feeding ground for scavenger birds like vultures.

Recommendations for solar energy:

- Habitat Management and Biodiversity Enhancement: maintenance of native ground cover between panels to prevent soil erosion and create microhabitats. This includes creating "biodiversity islands" by planting native species and installing features like insect hotels or water points. These actions transform the plant into a functional habitat that actively supports local wildlife populations, especially pollinators and small fauna, promoting habitat diversity and ecological connectivity.
- Wildlife-Friendly Infrastructure Design: Key infrastructure should be designed to be safe and permeable for wildlife. Fencing is elevated from the ground or equipped with small passages to allow terrestrial fauna to move freely across the site. Nocturnal lighting is minimized to avoid disorienting nocturnal species, thus reducing the facility's barrier effect and direct mortality risks.

Of course, the environment (mainly soil and vegetation) needs to be restored after construction. Restoration actions are fully developed in the section 4.7.2 of this document.

BOX 5: Habitat management: removing livestock carcasses

In the province of Guadalajara (Spain), 4 wind farms and 60 wind turbines have been in their operation phase since 2009. The area is characterised by the presence of several herds and some 7,000 head of cattle in extensive farming.
The Environmental Impact Statement established the need to carry out an environmental monitoring plan to record mortality and applied financial penalties for the deceased specimens, the amount depending on the category of threat to the species detected.

In view of the results obtained in the first 8 years of operation, the decision was taken to implement measures to reduce collisions with griffon vultures, this being the species with the highest number of collisions recorded. The focus of the measures is centred on two aspects. On the one hand, different studies are being carried out to increase knowledge of the movements of the species and the populations in the area through the marking of 57 adult specimens with GPS and/or remote reading tags and the census of breeding pairs in the main colonies in the area. On the other hand, work is being carried out with the local population to detect the needs and problems that could be affecting the presence of the species in the area. Within this block, the main measures carried out have been the renovation of water troughs to prevent the entry of vultures, the closure of conflictive dumping points due to their location, the creation of a new dumping point and the management of dead livestock both in the livestock facilities and in the field, removing all the animals and depositing them in the new dumping point.

The project is now in its 7th year, and the measures, especially carrion management, are still being implemented. The results obtained are fluctuating, with years in which collisions have been reduced and years with high values in line with the initial ones.

Although it has been shown that livestock management is key to the system, it is considered that there are uncontrollable variables, such as the weather, which affect the movements of the species and the risk of collision. Years with a higher proportion of fog, lower maximum temperatures and strong winds would mean higher collision risks.

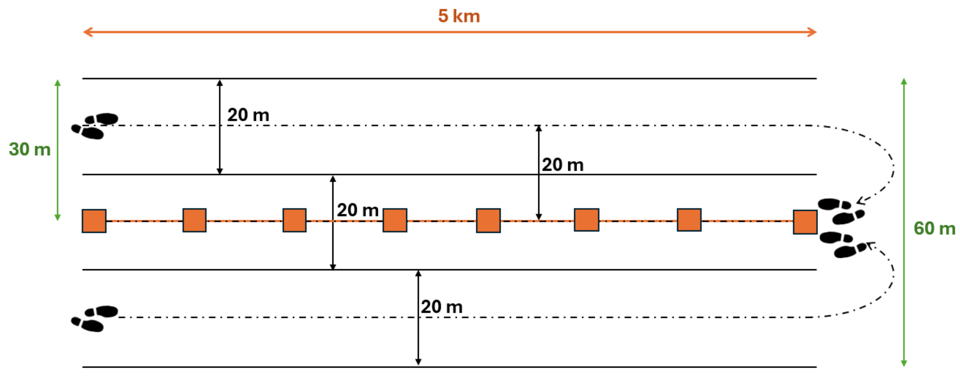
4.5

4.6 Operation

4.6.1 Environmental Surveillance

An essential part of the Environmental Surveillance is to assess the real impacts on biodiversity during the commissioning and operation phases to take actions to mitigate or stop significant negative effects. The surveillance objectives should be revisited after implementing the first year of environmental surveillance and routinely throughout the life of the project. The basic aspects of every environmental surveillance are given in the following lines:

- **Population monitoring:** keep the wildlife monitoring during the commissioning or operation phase shows the disturbance of renewable energies in comparison to the results of baseline studies. Moreover, this action may alert to new key species in the area in the case of recovery populations. Additionally, detailed population monitoring of target species to determine population size or trends could be crucial to determine the effects of recorded fatalities at the population level and to set a threshold for viability of the population in the scenario of the continuing facility operation. In this last case, estimating the number of breeders and productivity is the minimum necessary information.
- **Post-construction fatality monitoring**. It consists of field transects to count the number of fatalities and trials to address the potential sources of searching bias, resulting in the actual number of bird and bat collisions. There are several recommendations to avoid or reduce the bias in the mortality estimation:
    - **Sampling area and coverage:** In wind farms and solar plants, searches should be conducted by walking along parallel transects and perpendicular to blades or panels, spacing them from 4 to 6 meters, depending on the characteristics of the vegetation and the landscape. The ground search area must be: i) at least 10 % more than the rotor diameter in wind farms, ii) 25 meters' band on each side of the lines or panels in power lines and solar facilities. Covering the full surface of each facility is not always possible. In those cases, technicians will survey at least 30 per cent of the surface of the facility, selecting the areas to survey randomly. In the case of power lines, electrocution mortality should be assessed by visiting the base of the supports and a small radius around them (5 m is sufficient); if the number of pylons is very large, a representative sample of the different types of existing pylons can be selected. In the case of collision mortality, 5 km sections should be surveyed by conducting three parallel route lines, one under the line and two other routes 20 m apart, on both sides of the cables. In this way, 10 metres on each side (20 m observation band) can be observed on each route, covering a sampling band of 60 metres with the three parallel routes. Each section is checked by two samplers in a round trip, each of them completing a total daily distance of 10 km (Carrascal et al., 2016).



Maximum length: 5 km (depending on accessibility)
Sampling band width: 60 m
Observation band width: 20 m
Three parallel transects along the power line
Round trip survey (2 people)

Figure 2. *Methodology for collision monitoring on power lines (based on Carrascal et al., 2016)*

- **Duration**: the collision monitoring should be done at least for the first 3 years in operation. However, monitoring the facility for the whole lifetime is mandatory in several European countries.
- **Periodicity**: shorter periods of time between visits increase detection probability and fatality estimate precision, reducing confidence intervals of the statistical results. General search interval recommendation is set to every 2 weeks, but well-detailed studies justify performing a visit every 3 days (Ravache et al., 2024). If bats and small birds (less than 30 cm) are key species, the search interval should be less than 5 days due to the low persistence of their carcasses.
- **Detectability**: carcass detectability will differ between types of landscape (desert vs Atlantic scrubs), field technicians, terrains, and weather conditions. Trials should be performed in the absence of rain or fog, avoiding freshly fallen snow, and to account for the sources of bias correction: 1) searcher efficiency, 2) carcass persistence trials, and 3) the proportion of collisions that fall within searched areas (area correction). In the case of power line collision mortality, detectability can be assessed without the need for trials by analysing detection distances based on methods developed in the DISTANCE programme.
- **Statistical estimation**: GenEst is the most widespread program to estimate mortality. Link and information about this tool and statistical packages for DISTANCE programme are provided in available resources section.
- **Further suggestions:** the use of professionally trained dogs to detect carcasses has been proven to increase the searcher efficiency, particularly in small birds and bats (e.g., Domínguez del Valle et al., 2020; Mathews et al., 2013; Paula et al., 2011). The monitoring program should be adequately staffed and scheduled, with work carried out by an independent trained specialist. Otherwise, searcher efficiency may widely differ between technicians and environmental conditions.

- Searches to detect other potential risks are also part of the environmental surveillance. Some of these risks could be water poisoning by leaking fluids from solar panels and wind turbines, plastic pollution from coverings during commissioning, and any necessary fire precautions.

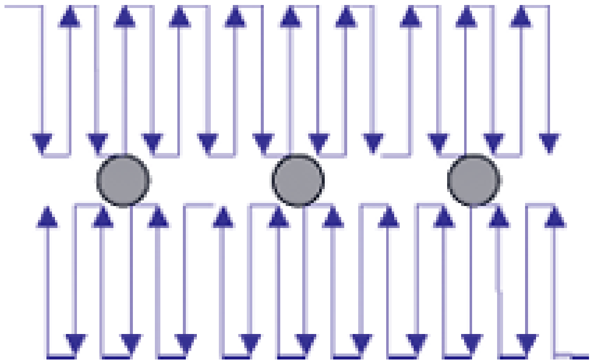


Figure 3. **Ground search scheme around wind turbines:** distance between transects should be 4-6 meters. Circles represent wind turbines (Extracted from *Atienza et al., 2011*).

4.6.2 Offsetting or compensatory measures

Offsetting, by definition, is a last-resort measure to be considered only after all avoidance and mitigation options have been exhausted. **For offsetting to be effective**, it must be accompanied by a clearly defined implementation **schedule** and a secured **financial commitment**. Evidence has shown that without an allocated budget, compensation actions are frequently postponed, weakened, or abandoned.

Offsetting strategies often involve habitat management interventions, such as improving environmental conditions, enhancing food availability, altering farming practices to favour wildlife, or installing artificial nests and refuges. Engaging local communities is not just good practice but a strategic necessity. Farmers, for example, may be incentivized to retire livestock from sensitive zones or adopt water management practices that enhance biodiversity. Local employment in wildlife monitoring can foster trust and generate social benefits, particularly in rural areas.

Population monitoring must continue throughout the project's lifecycle to verify whether compensation objectives are being met. Biodiversity Net Gain (BNG) frameworks, such as those implemented in the United Kingdom, offer structured methods to ensure that projects result in **measurable ecological improvement** (Bull and Brownlie, 2017). The purpose of BNG framework is to ensure that habitats for wildlife are left in a measurably better state than they were before the development of the renewable project. These frameworks rely on metrics, reference baselines, and long-term monitoring and should become standard requirements in project design (Panks et al., 2022).

In marine or offshore contexts, the reduction of bird mortality due to fishing bycatch has proven effective when supported by cooperation with local fishing communities and the use of mitigation technologies. Likewise, invasive species control, especially on breeding islands, can dramatically increase the reproductive success of seabirds.

In solar-specific contexts, offsetting usually includes agri-voltaic projects, mixing photovoltaic solar plants with agricultural practices (honey farms, sheep and several horticulture practices). Also, natural habitat enhancement actions (such as preserving native hedgerows, planting insect-rich floral strips, and creating rough grass margins) improve the coexistence of these renewable energies with nature.

Although the implementation of these measures may begin during the construction phase, they will be fully developed during the operational phase. To ensure compensatory or offsetting measures are effectively integrated into environmental policy and decision-making processes, the following prioritized set of actions is proposed. Each action includes a brief justification to enhance its operational clarity and facilitate strategic implementation:

- **Habitat Management Interventions:**
    - Environmental Condition Improvement: Prioritize restoring and maintaining habitats essential for target species' survival and reproduction.
    - Prey Availability Enhancement: Implement agricultural practices and habitat modifications specifically aimed at increasing the availability of key prey species.
    - Agricultural Field Adaptation: Shift agricultural practices toward wildlife-friendly cultivation or pasture management to enhance biodiversity.
    - Provision of Artificial Structures (refuges and nests): Implement this cost-effective measure selectively, monitoring its effectiveness closely, as results may vary significantly by species and location.
- **Local Community Engagement:**
    - Formal Agreements with Farmers: Develop and implement binding incentive programs encouraging agricultural practices beneficial to biodiversity (e.g., livestock retirement, water management).
    - Enhancement of Local Employment Opportunities: Support local economies by employing community members in habitat management and biodiversity monitoring roles, fostering long-term community support and sustainability.
- **Continuous Population Monitoring:**
    - Establish systematic monitoring programs to evaluate offsetting measure outcomes throughout project lifecycles, enabling adaptive management and swift action if objectives are not met (Moilanen et al., 2024).
- **Biodiversity Net Gain (BNG) Implementation:**
    - Mandate standardized BNG frameworks, using established metrics, baselines, and monitoring protocols to ensure transparent, measurable, and verifiable ecological outcomes. Reference existing successful frameworks (Moilanen et al., 2024; Rampling et al., 2024).

Recommendations for offshore wind farms:

- **Reduction of Anthropogenic Mortality:** Prioritize collaborative strategies with fisheries to reduce bycatch and implement rigorous invasive species control programs on key breeding islands (rats or cats as an example), significantly improving seabird reproductive success. Of course, hunting restrictions are necessary in the surrounding areas of wind farms.
- **Reduction of disturbance and enhancement of habitat management** at breeding colonies:
    - Management of habitats that support prey species. Provision of new feeding areas or artificial nesting sites.

- The closure, or enhanced management, of additional prey species fisheries (e.g. forage fish).
- The establishment of additional Marine Protected Areas – it requires management measures in place that exclude harmful activities i.e., designation alone is insufficient). Strictly protected areas that exclude all extractive and harmful activities are the most beneficial.
- Reduction of disturbance at sea: the reduction of recreational activity disturbance and shipping disturbance. or reduction in pressure from vessel movements, increase

Recommendations for solar energy:

- **Establishment of Habitat Buffers and Enhancements:** Integrate agri-voltaic practices, habitat corridors, and biodiversity-friendly management actions (e.g., native hedgerow preservation and insect-rich floral plantings) to enhance ecosystem services within solar installations.
- **Bat-friendly Lighting Protocols:** Enforce standardized guidelines mandating warm-spectrum, fully shielded lighting with motion and time controls, strictly prohibiting flood lighting within solar arrays to minimize impacts on bat populations.

Recommendations for power lines:

- **Retrofitting of existing dangerous lines.** In the case of projects of new power lines associated with the transport of electricity from new wind and photovoltaic plants, actions on existing dangerous lines in their vicinity may be a compensatory measure to be applied. In some countries (such as Spain), it is a widespread measure (authors' data).
- **Enhancing biodiversity in the vicinity of power lines.** The space around power lines can be used to implement measures to promote biodiversity. In the wide corridors through which the transmission lines run, it is possible to create small wetlands and meadows, install shelters for small vertebrates and invertebrates, plant bushes producing edible fruits, etc. (Ferrer et al., 2020; Šálek et al., 2020); also see 6.2.5. ELIA / RTE LIFE project). Artificial nests can be installed on the towers and pylons to encourage the reproduction of some interesting species, such as certain large birds of prey (Nicholson et al., 2022). On a smaller scale, the same type of measures can be installed on distribution lines.

BOX 6: Preserving populations and enhancing the coexistence of micro-mammals and solar plants

Sometimes, the best practice is to integrate the already present biodiversity in the new solar plant facility and enhance its distribution in human-altered habitats.

Between 2017–2019, an important population of Cabrera vole (*Iberomys cabrerae*) was found in the performed surveys before the solar plant's construction in Ceclavín, Cáceres (Spain). Under this situation, the developer decides to conduct a detailed monitoring program of the Cabrera vole population within the Oriol solar photovoltaic plant, to evaluate the species' response to the recent construction and operation of this energy infrastructure.

The study involved the mapping and ecological characterization of potential habitats across the plant's 800 hectares. 19 habitat patches were identified using aerial imagery and GIS tools. After that, intensive field surveys were carried out to detect signs of vole presence, such as runways, latrines, feeding remains, and tunnel entrances. A combination of these signs and photographic evidence confirmed the presence of *Iberomys cabrerae* in 17 of the 19 patches.

The study found that the voles primarily inhabit dense, stratified herbaceous communities dominated by perennial grasses and sedge species (e.g., *Scirpus holoschoenus, Juncus effusus, Cyperus longus*), with some areas also featuring protective woody plants. In addition, results indicated a marked increase in occupied areas compared to surveys conducted before the plant's construction, suggesting a population expansion. This growth is attributed to the elimination of key environmental stressors: the removal of cattle grazing, cessation of cereal cultivation, and active wildfire prevention. These changes improved the integrity and quality of hygrophilous grasslands and sedge meadows—key habitats for this moisture-dependent rodent.

The authors conclude that the current distribution of Cabrera vole within the solar plant is not only a sign of ecological resilience but also presents valuable opportunities for future research and conservation management, especially concerning population dynamics and habitat use in anthropogenically altered environments.


Source: Spanish Society of Mammalogist (SECEM). https://secem.es/galemys/galemys-36-2024-a5

4.6.3 Operation and maintenance recommendations

These facilities have an expected lifespan of 25-30 years or even more. Besides the mortality and population monitoring, some mitigation and remediation measures must be implemented, ensuring their adequacy and effectiveness (this list of measures is not exhaustive):

General recommendations:

- Limiting the number and speed of vehicle movements and fixed tracks. The maximum speed limit for road traffic at 30 km/h or less inside the facilities to reduce road killings of fauna.
- Reduce natural vegetation clearance to the minimum necessary for safety and construction work purposes. Cutting grass vegetation should be prohibited during the breeding season of ground-nesting birds to avoid the destruction of nests and clutches.
- Prevent the introduction of invasive species (e.g. washing vehicles before they enter the site).

Recommendations for power lines:

- Carrying out periodic reviews to check the condition of anti-electrocution and anti-collision measures and to verify their effectiveness.

Recommendations for wind farms:

- Wind turbine curtailment at 5-6 m/s of wind speed for bat conservation. Several studies in different countries have demonstrated the effectiveness of this mitigation measure.
- Schedule overnight stops during bats' high activity (especially summer).
- Automated detection system with video recording and/or bird surveys
- Collaboration between professional technicians or NGOs at fieldwork and developers to control the periods of shutdown depending on the timing of migration or breeding of target species.

Recommendations for solar energy:

- Improve the connectivity of terrestrial wildlife:
    - Check permeable fences for wildlife to reduce the loss of connectivity. Grass growth, objects or plants moved by wind can obstruct the gaps in the security fences to facilitate animal movements.
    - In the case of installations with a side length of more than 500 meters on at least one side, creating migration corridors for large mammals, the width and planting of which take into account the local conditions.
- Mowing to promote biodiversity is carried out at most twice a year, and the mown material is cleared away, or the area is grazed as portion pasture with a stocking density adapted to the area yield to promote biodiversity.
- Solar panels should be situated at 80 cm or more above the ground to improve the growth of native plants and enhance the green cover of the soil.
- It is recommended to leave 3 meters between the rows of solar panels and in line with the slope to facilitate the watercourse inside the solar plant.
- The facility is operated in a soil-conserving manner by:
    - Avoiding the use of herbicides and pesticides and promoting the growth of local vegetation.

- The facility is only cleaned with cleaning agents if these are biodegradable and cleaning is not possible without the use of cleaning agents.

The measures committed to and their results should be shared with the competent authorities, and there should be legal consequences, such as penalties, for the developers if requirements are not met.BOX 7: Shutdown-on-Demand (SDOD) Systems in preventing bird mortality in wind farms

The Barão de São João wind farm, located in the Sagres region of Portugal, lies along a major migratory flyway used each autumn by around 5,000 individuals of 30 species of soaring birds. As a condition of its environmental license, a strict mitigation protocol was implemented: The Radar Assisted Shutdown on Demand (RASOD) system, aimed at reducing bird collision risks.

The protocol combined a radar-based detection system with a perimeter of trained observers to monitor approaching soaring birds. Turbines were shut down whenever pre-defined thresholds for intense migration or the presence of threatened species were met. Initially, shutdowns were executed by wind farm staff upon request from the monitoring team (MT), but later, the MT was granted direct access to SCADA (the wind farm's remote turbine control system).

Over five consecutive autumns, no soaring bird fatalities were recorded, even though 55% of birds crossed the wind farm at high-risk altitudes. System efficiency improved with the MT's growing experience and their direct control via SCADA: average annual shutdown time dropped from 105 hours in the first year to just 15 hours in later years—representing only 0.2–1.2% of the wind farm's annual operating hours (Tomé et al., 2017).

The use of human observers alone is also effective. In the province of Cádiz, Southern Spain—an area situated along a major migratory flyway between Europe and Africa—a turbine shutdown protocol was implemented across 269 wind turbines to mitigate collisions with soaring birds, particularly the Griffon Vulture (*Gyps fulvus*). Beginning in 2008, the protocol involved trained observers monitoring bird activity and ordering turbine shutdowns when high-risk conditions were met, such as the presence of large flocks or the proximity of vulnerable species. Turbines were stopped individually or in clusters, depending on bird flight paths and wind conditions.

Over a 13-year monitoring period, this selective shutdown approach proved highly effective. Vulture mortality was reduced by **50% within the first two years**, and by **over 90% (specifically 92.8%)** by the end of the study period. Collisions of other soaring birds were reduced by approximately 61.7%. Remarkably, this was achieved with minimal impact on energy production: turbine stoppages accounted for **less than 0.51%** of potential annual energy output (Ferrer et al., 2022).

Scientific studies and real-world applications have demonstrated that SDOD systems can lead to significant reductions in bird mortality, often approaching 100% avoidance of fatalities during critical migration periods. Importantly, these benefits can be achieved with minimal loss of energy production—typically less than 1% of annual operating time—making SDOD a highly cost-effective and ecologically responsible solution (Smallie et al., 2025).

Sources:

Tomé et al, 2017: https://www.researchgate.net/publication/314880612_Radar_Assisted_Shutdown_on_Demand_Ensures_Zero_Soaring_Bird_Mortality_at_a_Wind_Farm_Located_in_a_Migratory_Flyway

Ferrer et al., 2022: https://doi.org/10.1016/j.gecco.2022.e02203

Smallie et al., 2024: https://birdlife.org.za/wp-content/uploads/2025/06/SDOD-Handbook-BirdLIfe-SA-June-2025.pdf

4.7 Repowering/Decommissioning

4.7.1 Decommissioning recommendations

Decommissioning presents its own set of environmental responsibilities and should be treated with the same rigor as the project's development phase. Dismantling infrastructure can cause short-term disturbance to soil, vegetation, and local fauna. If not properly managed, decommissioning can result in lasting degradation of ecosystem functions and loss of biodiversity value, particularly if the site is simply abandoned or converted to incompatible land uses.

A well-executed decommissioning plan must include site-specific restoration objectives, aiming to restore or improve the ecological integrity of the area. This includes regrading and stabilizing soils, re-establishing natural drainage patterns, replanting native vegetation, and removing artificial barriers to wildlife movement. Restoration must consider both the original habitat type and the current ecological potential of the site. In some cases, full ecological restoration may not be possible or desirable; instead, ecological enhancement strategies can provide an alternative solution.

Importantly, decommissioning and repowering must be anticipated well in advance, not improvised at the end of a project's life. Environmental management plans should include a lifecycle perspective from the outset, with clearly defined responsibilities, timelines, and funding mechanisms for end-of-life interventions. Regulators and permitting agencies have a vital role to play here, by requiring enforceable decommissioning plans and setting ecological performance standards for restoration.

General recommendations:

- Avoiding decommissioning work during sensitive periods of species’ lifecycles. Scheduling the works as in the commissioning phase is recommended.
- Minimising habitat disturbance and soil destruction during infrastructure removal.

- Minimising noise associated with infrastructure removal procedures, particularly in the breeding season.
- Accounting for and addressing potential social and ecosystem service impacts arising from biodiversity mitigation.
- Managing waste disposal and implementing a protocol for rapid management of any chemical leaks or spills, as in the operation phase.
- Ensuring the reuse, recycling or disposal of decommissioned components.
- In case the project was located in a sensitive area or a protected area, like Natura 2000 or Emerald network area, the impacts of the repowering process should be re-evaluated, including nature restoration as a priority.

4.7.2 Restoration actions

Restoration should be the last chance to reach the net gain according to the mitigation hierarchy. The European legislation (The Birds and Habitat Directives or Environmental Impact Assessment EU directives) obliges, when there is not alternative solution, to compensate the area and habitats affected by a development project with the compensation of equivalent habitat type in a new site, or by the expansion of an existing protected area.

- Recovering or enhancing habitats that serve as refuges or main foraging areas for endangered or specialist species should be a priority.
- To facilitate natural revegetation, it is preferable to use soil, mulch and vegetation debris. Retaining and storing topsoil and subsoil stripped from the construction areas to be reinstated could be a low-cost and environmentally friendly solution.
- Using local species for landscaping and rehabilitation works. Never use exotic species.

BOX 8: ELIA / RTE LIFE+ project: manage and restore areas under high-voltage overhead power lines in Belgium and France

The ELIA / RTE LIFE+ project, officially known as “LIFE Elia-RTE: Power Lines and Nature,” is an innovative cross-border biodiversity restoration initiative implemented in Belgium and France under the EU’s LIFE+ programme. This collaborative project, which ran from 2011 to 2017, was led by the Belgian transmission system operator Elia and the French operator RTE, with the support of various local stakeholders, landowners, and nature conservation organizations. Its main objective was to rethink the management of vegetation under high-voltage overhead power lines, transforming these often neglected or intensively cleared corridors into valuable ecological corridors that enhance biodiversity and connect fragmented habitats.

Traditionally, areas beneath power lines have been maintained through costly and repetitive mechanical clearing to prevent tall vegetation from interfering with transmission infrastructure. The LIFE Elia-RTE project proposed a more sustainable, nature-based approach by managing and restoring these spaces in ways that benefit both grid safety and biodiversity. One of the project’s core goals was to create semi-natural open habitats such as flowering meadows, wetlands, and woodland glades, which provide critical resources for many plant and animal species, including pollinators, birds, and small mammals.

Key actions included planting native shrubs and low-growing vegetation, rewetting certain plots to create wetlands, introducing extensive grazing by large herbivores to maintain open habitats naturally, and developing ecological monitoring protocols to measure the positive impact on local biodiversity. The project also focused on active stakeholder engagement, working closely with local communities, landowners, forest managers, and conservationists to raise awareness about the potential of these corridors as green infrastructure. Educational trails and interpretive panels were installed along some restored sites to inform the public and showcase the benefits of this multi-functional land use.

The ELIA / RTE LIFE+ project demonstrated that well-managed transmission corridors can act as ecological networks that connect isolated habitats and support species dispersal, thereby playing a crucial role in landscape-scale conservation strategies. By combining technical grid safety requirements with environmental best practices, the project not only reduced maintenance costs in the long term but also created new opportunities for local biodiversity, proving that transmission system operators can be active contributors to Europe’s green infrastructure and biodiversity objectives.

Source: http://www.life-elia.eu/.

4.7.3 <u>The relevance of new projects: Repowering opportunities</u>

Repowering brings the opportunity to address existing negative biodiversity impacts. Analysing the monitoring dataset collected during the operation phase is a good first step to detect potential impacts of the previous project on biodiversity and evaluate the best approach to avoid them in the repowering project.

Several studies have shown that the replacement of old wind farms by a smaller number of larger turbines with no change in overall capacity has a positive impact on bird conservation (Huso et al., 2021). As a general recommendation, taller turbines reduce the probability of collision with a high number of species of birds and bats (Roemer et al., 2017; Schaub et al., 2024). In fact, ground clearance distance above 60 meters significantly reduces the probability of collision with wind turbines of 5 from 6 species of raptors (i.e. Common bustard, Red kite, Montagu´s harrier, Hen harrier and Marsh harrier in a recent study (Schaub et al., 2024)). In any case, when implementing new wind turbines, it is essential to reassess collision risks, since increased rotor height and swept area may also result in higher bird and bat mortality at greater altitudes. A thorough understanding of existing impacts and the most sensitive area(s) within the current site is crucial for minimizing environmental effects in repowering projects.

In the case of solar facilities, changing CSP technology to photovoltaic seems to significantly reduce bird mortality. CSP consume much more water than PV solar facilities, and the collision risk posed by PV panels is likely low compared to the registered mortality at CSP plants. Moreover, new materials and progressive evolution in the technology of photovoltaic panels should shortly allow the production of the same energy using less space, delivering benefits for bird and bat conservation, and decreasing the environmental trade-offs of solar energy. Therefore, approved plans for solar energy projects must contemplate repowering conditions.

BOX 9: Repowering: an opportunity to reduce the negative impacts on biodiversity

Old wind farms from the early 2000s in Europe were installed in a different context, when the current consequences on birds and bats were unknown or overlooked. Beside we need to advance in the standardized protocols in Environmental Surveillance, the collected data during the operation phase may be relevant signalling the most dangerous areas for birds.

Using transects and mortality information compiled during Environmental Surveillance in the last 20 years in a wind farm in the north of Soria (Spain) revealed the areas with higher risk of bird collision. The technicians implement a kernel density estimation model from the observed species to estimate the zones that concentrate the highest activity and the highest recorded mortality, considering the sensitivity of each species to wind farms and the conservation status.

Therefore, this methodology has allowed the developer to sit the new wind turbines in the areas that minimize the impact on biodiversity.

Source: https://www.cww2025.org/programme/program

4.8 Summary table of scheduling measures

Table 1. Summary table of described measures and actions in section 4 and the corresponding phase in a renewable project.

Measure or Action	Feasibility and design	Pre-construction	Construction	Operation	Decommissioning or Repowering
Site selection	■				
Sensitivity mapping	■				
Baseline studies		■			
Population monitoring		■	■	■	
Scheduling to minimise disturbances			■		■
Systems of Shutdown of Demand			■	■	
Installation anti-electrocution and anti-collision measures*			■		
Operational curtailment				■	
Mortality monitoring				■	
Vegetation control				■	
Checking of anti-electrocution and anti-collision measures				■	■
Checking of fences				■	
Control and management of hazardous waste			■	■	■
Restoration actions			■	■	■
Lost biodiversity compensatory actions**			■	■	■
Data sharing	■	■	■	■	■
Public participation and local engagement	■	■	■	■	■

*Including: painting of blades, visual or acoustic deterrence devices, and physical deterrence.

**Including: environmental condition improvement, systematic carcass removal, prey availability enhancement, shift agricultural practices, provision of refuges and nests, reduction of other sources of anthropogenic mortality, and retrofitting of existing dangerous lines.

5 Gaps and opportunities to take a step forward on renewable energies

5.1.1 Data availability and sharing information

Governments, NGOs, environmental consultancy companies, and developers collect thousands and millions of spatially explicit biodiversity data each year.

Population monitoring programs show trends, productivity, nesting sites, phenology, and dynamics of species. GPS devices recover migratory pathways, biodiversity hotspots, daily movements, and home range ranks of species of interest. Environmental surveillance programs of energetic infrastructures record mortality rates of birds and bats and point out the most conflictive characteristic of each project (dimension of turbines, specific zones in the project, type of energy (CSP farms), and new anthropogenic food sources). Piece by piece, these patches of information help to set up the complete picture and make the best decisions for each area and project, improving the whole mitigation hierarchy process.

However, this information usually remains unknown to the other interlocutors and participants. Some handicaps to sharing this data are the absence of official repositories, a lack of standardised methodology, and the reluctance to include sensitive information. Moreover, there is a reticence to make information available without any exchange, but as this information has been collected through public financing or is under the public information process in many cases, there is no reason to retain the data.

Therefore, promoting data sharing will increase the information available to everyone and allow solutions to be implemented based on the best criteria.

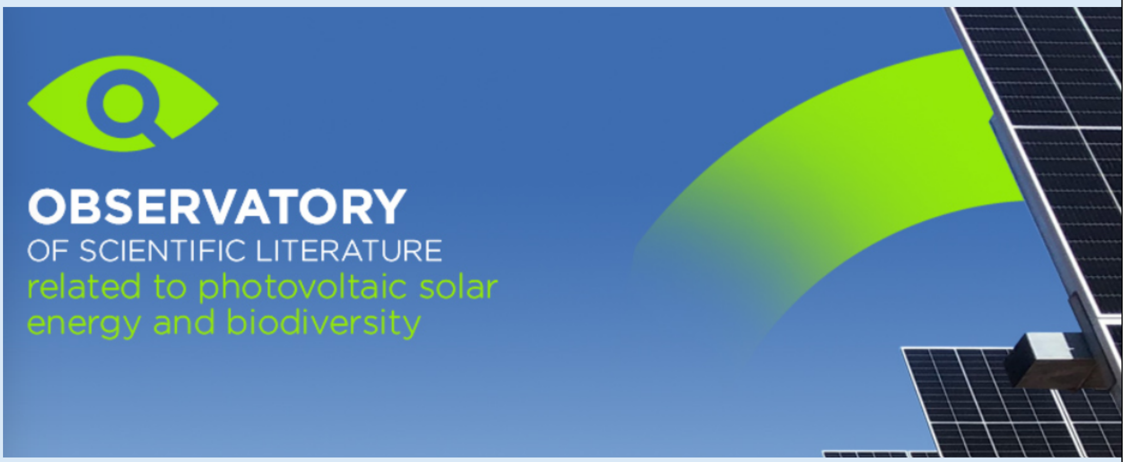
BOX 10: Repository from Steppe Forward Cathedra

The Cathedra Steppe Forward, from the Autonomous University of Madrid and the Center of Forestry Science and Technology and funded by Total Energy, has created a bibliographic repository.

The main objective of the Observatory of Scientific Bibliography Related to Photovoltaic Solar Energy and Biodiversity is to provide an updated repository of knowledge about solar energy and it's impacts and measures on biodiversity that was validated by scientific criteria. The tool also facilitates the search, consultation and access to scientific knowledge for individuals interested in the management and conservation of biodiversity linked to areas affected by photovoltaic solar energy infrastructure, including filters to select the most accurate topics and scientific articles. The Observatory compiles publications used in a systematic literature review on the impacts of photovoltaic solar energy on different components of biodiversity and on mitigation measures to be applied to minimize such impacts. This Observatory is periodically updated with new knowledge advances generated worldwide on this topic.

This tool includes a brief summary of the main results and conclusions derived from the abstract of the work itself for each publication, as well as a link to the original publication.

Developers and consultants have been shown the necessity of this kind of repositories to facilitate the searching process and access to the newest scientific knowledge.



Source: Catedra Steppe Forward. https://steppeforward.eu/observatorio-bibliografia/

5.1.2 Model validation

There is an opportunity to use the gathered information to enhance the development of methodologies and technologies to detect and avoid the risky areas for renewable energies.

For example, despite the high number of variations of Collision Risk Models (at least 52 according to Cook et al., 2025), only a couple of them have been validated to assess whether their estimates of risk are accurate. The impossibility of collecting carcasses at offshore wind farms, the troubles in detecting unbiased carcasses at onshore wind farms, the variety of environments, and the obstacles to accessing and collecting this information at high spatial resolution make it difficult to determine mortality rates at each turbine to assess the accuracy of CRM predictions.

The scoring of sensitivity maps constitutes another example. Each country or region has developed its own scoring system, using the information available and the best expert criteria, but almost none of them have validated their sensitivity mapping process with the new information. Updating and validating those maps, as governments and other institutions collect new information, will substantially improve the impact assessment of renewable energies.

As a result, there is often a lack of confidence in the use of model outputs only based on expert criteria for consent decisions, especially when experts do not agree on the parameters or type of model.

Validating these models should be a priority for developers and consultancy companies, and a request from policymakers. Only moving from expert criteria to validated models will increase transparency and security in the obtained results, undoubtedly legitimating the decision-making process.

5.1.3 Methodologies for synergic and cumulative impact assessment

The cumulative and synergic impacts of renewable energies are still not properly understood or effectively managed. While estimating synergic effects seems to be out of reach of the current knowledge, some approaches have appeared in recent years in the context of cumulative impacts.

Most of these tools and mechanisms work similarly. They consist of a workflow or roadmap in which each impact can be evaluated separately, and the sum of all the different detected impacts on each biodiversity element will give a final value of the cumulative impact of the renewable infrastructure on the environment.

However, all these tools have certain unclear factors. Determining the extension of the impacts and pressures, the infrastructures or type of anthropogenic elements that need to be considered (wind farms, solar panels, roads and highways, agricultural fields, etc.), and the combined results at the population or, even more, at the community level is essential to advance in this intriguing issue.

In addition, the main limitations are the time and resources necessary to implement a full adaptive study of the synergic and cumulative impacts in each Environmental Impact Assessment.

Further research is necessary to solve some questions, such as: What is the range extension to consider that mortality from other wind farms is impacting our study population? Should habitat loss from urbanisation or intensification of agriculture be added to habitat loss? Are the modelled distributions of species included to estimate the impact of a new infrastructure of renewable energy?

5.1.4 Appropriateness of specific common rules

In the case of power lines, generic legislation on environmental impact has proved insufficient to address the problem. The existence of specific legislation, establishing geographical priorities and mandatory specific technical requirements, has proved to be effective in the case of some countries as Spain, Germany and Slovakia, and has also encouraged the development of new technical solutions by companies in the sector. A European legal framework with similar characteristics to the Spanish one would be desirable.

Perhaps specific legal frameworks for wind farms and photovoltaic plants would also be effective.

6 Conclusions

To conclude this document, the following items are the most relevant advice to develop renewable energies in harmony with biodiversity:

1. **Spatial planning and site selection** are the **cornerstone** for developing renewable energies in harmony with biodiversity. By placing projects in the least sensitive areas for biodiversity, we can minimize the negative impact. To address the remaining negative impact, the mitigation hierarchy should be followed to achieve net-zero or even net-positive impact on biodiversity.
2. **Prioritization** of the dual or multiple use of existing infrastructures, buildings, and highly human-altered lands.
3. **Coordination** between different stakeholders and statements for **better development of the grid** in accordance with renewable energies**.**
4. Promoting **data standardisation and** establishing **common rules and regulations** for minimum essential requirements will help to clarify and enhance the transparency of renewables development and to evaluate the impact at regional, national and transboundary levels.
5. Mitigation and offsetting should be **scheduled, priced, and evaluated**. Only systems with certified efficacy may not need a protocol to confirm their efficacy.
6. **Offsetting** should be the **last chance** in any project and due to major causes. It is not admissible to set up projects with a high impact in sensitive areas at the expense of offsetting measures.
7. **Monitoring** the impacts of the renewable projects during the construction and operation phases (throughout the Environmental Surveillance) **and adapting to** the new circumstances to minimize the negative effects of the renewable projects.
8. There shall be **legal consequences and implications** for renewable energy developers to ensure compliance with mitigation, avoidance, and compensation measures. Such consequences may include financial sanctions, disqualification from engaging in the development of new projects for a specified period, or the decommissioning of conflicting infrastructure
9. **Data sharing** should be mandatory, minimizing the sampling effort in some cases (so reducing costs in the initial phases of projects) and improving the available information to select the best places or measures based on the best knowledge available. Exceptions for breeding sites of endangered species or intellectual property issues should be considered.
10. **Transparent consultation processes and early and effective public engagement** in decision-making aid in mitigating conflicts and identifying local issues and necessities proactively. This work philosophy prevents delays and improves project acceptance.
11. Providing **new tools based on the best knowledge available** needs to be a priority for national governments. For example, investment for an appropriate and accurate **cumulative effects assessment** of new projects, particularly the impact of habitat loss and mortality on population dynamics.

7 Available resources

Here is a list of already available resources, including: type of resource, a short description, Owner or creator of that resource, and a link to the resource (if it is available). We also add a symbol to indicate the type of energy (wind, solar, or power lines) to which the resource will be useful.

7.1 Sensitivity maps

BirdLife Europe & Central Asia – Green Power: Aligning renewables with biodiversity to accelerate the energy transition – October 2025. It is a compilation of sensitivity maps from the EU members, including: 19 from onshore wind, 14 from offshore wind, 2 from solar, and 7 from electricity grid. *Birdlife International*. https://www.birdlife.org/wp-content/uploads/2025/10/paper-2energy-report_online_Smallest.pdf

Avistep: sensitivity maps of bird species from several African and Asian countries for renewable energies at 5 km x 5 km resolution (India, Nepal, Thailand, Vietnam, Kenya, Lao PDR, Uzbekistan, and Egypt are currently available). *BirdLife International*. https://avistep.birdlife.org/

The wildlife sensitivity mapping manual: practical guidance for renewable energy planning in the European Union and providing tools and resources to elaborate sensitivity maps. *European Commission, BirdLife International and Arcadis*. https://op.europa.eu/en/publication-detail/-/publication/a3f185b8-0c30-11eb-bc07-01aa75ed71a1/language-en

Energy and Industry Geography Lab: Map of sensitivity and protected areas, electricity grid, and renewable energies infrastructure. *European Commission*. https://energy-industry-geolab.jrc.ec.europa.eu/

Integrated Biodiversity Assessment Tool: compile biodiversity information from four international validated organizations and provide graphs and short reports in the paid tier. *BirdLife International, Conservation International, IUCN, UN WCMC*. https://ibat-alliance.org/

7.2 Migratory species

Euro Bird Portal: this website shows observations of migratory birds in a week-by-week timeline, allowing to visualize the main migratory routes in Europe of your target species. *European Bird Census Council*. https://eurobirdportal.org/ebp/en

Migratory Birds Sensitivity Mapping Tool: provides information on the distribution of soaring bird migration between Europe, the Middle East and East Africa. *Convention on the Conservation of Migratory Species of Wild Animals and Birdlife International*. https://maps.birdlife.org/MSBtool/

Energy Task Force: is a multistakeholder platform that compiled relevant information and recommendations for the members, mainly focused to wind energy and the electricity grids impact on migratory birds. Convention on the *Conservation of Migratory Species of Wild Animals (CMS)*. https://www.cms.int/en/taskforce/energy-task-force

7.3 Biodiversity distribution and habitat information

Database of Global Data Sources for Biodiversity Conservation Monitoring: includes 202 global data sources of distribution, monitoring, pressures and threats to analyse the impact on biodiversity. *Species Monitoring Specialist Group of IUCN*. Web version: https://datasources.speciesmonitoring.org/; and pdf version: https://www.speciesmonitoring.org/data-sources.html

The critical sites Network tool: provides information about important areas for waterbirds in Europe, Middle East and Africa. *Wetlands International*. https://criticalsites.wetlands.org/en

Protected planet: provides complete and most up to date geographical representation and information on protected areas and other effective area-based conservation measures (OECMs) globally. *UN Environment World Conservation Monitoring Centre (UNEP-WCMC) with support from IUCN and its World Commission on Protected Areas (WCPA).* https://www.protectedplanet.net/en

Global Dynamic Land Cover: provides spatial information on different types (classes) of physical coverage of the Earth's surface at global level that was extracted from Copernicus satellite images. *European Environment Agency (EEA)*. https://land.copernicus.eu/en/products/global-dynamic-land-cover.

Corine Land Cover (CLC): offers a standardized pan-European land cover and land use inventory with 44 thematic classes. *European Environment Agency (EEA)*. https://land.copernicus.eu/en/products/corine-land-cover

African land cover: is a land cover classification map of Africa at 20 m resolution that was created using satellite images. *European Space Agency (ESA)*. https://www.esa.int/ESA_Multimedia/Images/2017/10/African_land_cover

The Global Biodiversity Information Facility (GBIF): an international network that compiles and share biodiversity spatial data. *The GBIF Network*. https://www.gbif.org/

eBird: presents an extensive variety of maps about bird distribution and bird trends based on citizen science, but always with caution, as it is not an official source of bird distribution. *Cornell Lab*. https://ebird.org/

Movebank: This website collects information from animals marked with GPS devices, where some of them are open to be visualised and others to be downloaded. *Max Planck Institute of Animal Behavior, the North Carolina Museum of Natural Sciences, the Senckenberg Society for Nature Research, and the University of Konstanz*. https://www.movebank.org/cms/movebank-main

The European Breeding Bird Atlas (EBBA): shows breeding areas, abundance and how their distribution has changed since the 1980s. *European Bird Census Council*. https://ebba2.info/maps/

Pan-European Common Bird Monitoring Scheme (PECBMS): provides population trends of bird species, using large-scale and long-term monitoring data. *European Bird Census Council*. https://www.ebcc.info/what-we-do/pecbms/

The EMMA database: represents maps of European mammals (including bats) using data from the Atlas of European Mammals. *European Mammal Foundation*. https://www.european-mammals.org/php/mapmaker.php

African bat database: distribution of 266 species of bats from sub-Saharan Africa. *Monadjem et al*. https://www.nature.com/articles/s41597-024-04170-7

7.4 Databases and hosts

Global energy monitor is platform which provides open resources such as maps and information about global energy infrastructure. *Global Energy Monitor*. https://globalenergymonitor.org/projects/global-wind-power-tracker/tracker-map/

Open Infrastructure Map is a view of the world's infrastructure mapped based on the information provided in the OpenStreetMap database and provides spatial representation about electricity grid at global level. *Open Street Map*. https://openinframap.org/

Solar and Wind Energy Resource Assessment (SWERA) was a collaboration with a mission to provide information on renewable energy resources around the world that concluded in 2011, but provides links for more updated resource data. https://openei.org/wiki/Solar_and_Wind_Energy_Resource_Assessment_(SWERA)

Life project "SafeLines4Birds 2023-2028": Its website maintains a collaborative database that compiles scientific studies on bird-power lines interactions, https://www.safelines4birds.eu/database

Renewables Grid Initiative (RGI): Its website compiles examples of best practices in the socially and environmentally responsible modernisation of the electricity grid. *RGI is an NGO for dialogue between transmission system operators (TSOs) and non-governmental organisations (NGOs)*. https://renewables-grid.eu/activities/best-practices.html

Tethys: is a repository that hosts documents, information, and resources about the environmental effects of marine energy and wind energy. *Supported by the USA government*. https://tethys.pnnl.gov/

The Observatory of Scientific Bibliography related to Photovoltaic Solar Energy and Biodiversity: updated repository of knowledge about impacts and measures on biodiversity in solar projects. *The Autonomous University of Madrid, the Center of Forestry Science and Technology and funding by Total Energy*. https://steppeforward.eu/en/bibliography-observatory/

Library from the IUCN organization: includes databases, tools, standards, guidelines and policy recommendations about renewable energies and electricity grid. *IUCN*. https://iucn.org/resources

7.5 General Guidance Documents

Industry guidance for early screening of biodiversity risk for solar energy development: brief and graphic guide with tools and recommendations to solar energy (especially photovoltaic) projects in the early stage. *IUCN and The Biodiversity Consultancy*. https://iucn.org/resources/grey-literature/industry-guidance-early-screening-biodiversity-risk-solar-energy

Solar, Biodiversity, Land Use: Best Practice Guidelines. This document provides advice about EU legislation and recommendations to incorporate an environmental perspective in solar projects. *Solar Power Europe and BirdLife International*. https://www.solarpowereurope.org/insights/thematic-reports/solar-biodiversity-land-use-best-practice-guidelines

Spatial planning for wind and solar developments and associated infrastructure: a guidance that explain what, how and when implement spatial planning. *IUCN and The Biodiversity Consultancy*. https://portals.iucn.org/library/node/52091

Guidelines for Assessing the Impact of Wind Farms on Birds and Bats: provides information for wind energy in Europe, including planning, mitigation measures, and recommendations to environmental surveillance. *SEO/Birdlife*. https://seo.org/wp-content/uploads/2014/10/Guidelines_for_Assessing_the_Impact_of_Wind_Farms_on_Birds_and_Bats.pdf

Opportunities for enhancing biodiversity at wind and solar energy developments: provide opportunities, recommendations and considerations to enhance biodiversity in renewable energy projects. *IUCN and The Biodiversity Consultancy*. https://portals.iucn.org/library/node/52144

Natural Capital Best Practice Guidance: Increasing biodiversity at all stages of a solar farm's lifecycle. It explains the mitigation hierarchy and gives examples and recommendations to include biodiversity in all phases of the project. *Solar Energy UK*. https://solarenergyuk.org/resource/natural-capital-best-practice-guidance/

Wind energy developments and Natura 2000: provide guidance on all phases of wind energy projects to ensure compatibility with the provisions of the Habitats and Birds Directives. *European Commission*. https://op.europa.eu/en/publication-detail/-/publication/65364c77-b5b8-4ab6-919d-8f4e3c6eb5c2

Electrocutions & Collisions of Birds in EU Countries: The Negative Impact & Best Practices for Mitigation. This document provides a whole vision of the impact of the electricity grid on birds. *Raptor Protection of Slovakia and NABU*. https://www.birdlife.org/wp-content/uploads/2022/10/Electrocutions-Collisions-Birds-Best-Mitigation-Practices-NABU.pdf

Wildlife and power lines: Guidelines for preventing and mitigating wildlife mortality associated with electricity distribution networks. *IUCN*. https://iucn.org/resources/publication/wildlife-and-power-lines

Sustainable deployment of renewable energy technologies and power lines: avoiding and mitigating negative impacts on biodiversity. Brief guideline with essential information on the mitigation hierarchy and an extensive list of useful resources. *Convention on the Conservation of Migratory Species of Wild Animals*. https://www.cms.int/sites/default/files/document/cms_etf6_doc.6_information-resources_e.pdf

Mainstreaming Biodiversity into Renewable Power Infrastructure: shows opportunities for including biodiversity into renewable energy sector planning and policy to deliver better outcomes for nature and the climate. OECD. https://www.oecd.org/en/publications/mainstreaming-biodiversity-into-renewable-power-infrastructure_357ac474-en.html

Guidelines for consideration of bats in wind farm projects: provides guidelines for assessing the impact of wind turbines in all the phases of the project and gives some recommendations about mitigation measures. *UNEP/EUROBATS*. https://www.eurobats.org/publications/eurobats_publication_series/eurobats_publication_series_no6

Guía para la elaboración de estudios de impacto ambiental de proyectos de plantas solares fotovoltaicas y sus infraestructuras de evacuación: this provides examples and recommendations about Environmental Impact Assessment on solar plants. *Spanish Ministry Of Environment* (only available in Spanish by now). https://www.miteco.gob.es/content/dam/miteco/es/calidad-y-evaluacion-ambiental/temas/guiaelaboracionesiaplantasfotovoltaicassgea_tcm30-538300.pdf

Nature-positive energy principles for environmental siting and permitting of solar, wind, and grid infrastructure: provides advice for developers on environmentally friendly practices and the best way to meet environmental requirements. *IRENA*. https://wwfint.awsassets.panda.org/img/original/irena-nature-positive-energy_principles-2025-embargo.pdf

Levers for taking biodiversity into account in the development of renewable energies: promotes levers for integrating biodiversity into renewable projects for stakeholders. Observatory on Renewable Energies and Biodiversity. https://professionnels.ofb.fr/fr/doc/leviers-prise-en-compte-biodiversite-dans-developpement-energies-renouvelables

7.6 Cumulative effects

EolPop: an app to assess the impact of wind farms on bird mortality at population level. *CNRS and other French institutions*. https://shiny.cefe.cnrs.fr/en_eolpop/

Guidance on biodiversity cumulative impact assessment for wind and solar developments and associated infrastructure: aims to help support biodiversity conservation and improve the cumulative impact assessment approach. *IUCN and The Biodiversity Consultancy*. https://portals.iucn.org/library/node/52090

7.7 Ecological Non-Price Criteria

Making nature count in offshore wind auctions: informs the design of ecological non-price criteria and their integration in offshore wind energy auctions. *Birdlife International*. https://www.birdlife.org/wp-content/uploads/2025/05/BirdLife_NPC-report_Online-Version.pdf

Beyond price: How non-price criteria in renewable energy auctions can help deliver for climate, nature and people. It provides key policy recommendations, drawing on emerging best practices of ecological non-price criteria. *The Nature Conservancy*. https://www.nature.org/content/dam/tnc/nature/en/documents/n/o/non-price-criteria-TNC-europe.pdf

Unlocking the Potential of Non-Price Criteria in Wind Energy Auctions: provides recommendations for states to implement ecological non-price criteria in wind energy auctions. *WWF*. https://www.natureza-portugal.org/?18641841/NPC-in-wind-energy-auctions-position-paper

7.8 Mortality detection and estimation

GenEst: an app to estimate mortality of birds and bats from carcasses detection at wind farms. *U.S. Geological Survey*. https://connect.west-inc.com/GenEst/

Eoldist: an app to estimate the minimum detection distance to avoid collisions. *CNRS and other French institutions*. https://shiny.cefe.cnrs.fr/en_eoldist/

Collision risk model spreadsheet: designed to estimate collision risk based on Band et al. 2007 model. *Scotland´s Nature Agency*. https://www.nature.scot/doc/collision-risk-model-onshore-wind-farms-spreadsheet-2024

Avian stochastic collision risk model (sCRM or stochCRM): a shiny app or R package that allows to estimate marine bird mortality in the North Sea, built from Band (2012) and Masden (2015) models. *Marine Scotland*. https://www.collisionrisk.org/stochcrm

Post-construction Bird and Bat Fatality Monitoring for Onshore Wind Energy Facilities in Emerging Market Countries: is a complete handbook about mortality detection and estimation of birds and bats during the Environmental Surveillance. *IFC, EBRD and KfW*. https://www.ifc.org/en/insights-reports/2023/bird-bat-fatality-monitoring-onshore-wind-energy-facilities

Assessment, mitigation and monitoring of onshore wind turbine collision impacts on wildlife: a review of peer-reviewed literature to provide a transparent summary of evidence and knowledge gaps associated with the collision of biodiversity to wind farms. *Arthur Rylah Institute for Environmental Research; Department of Energy, Environment and Climate Action; and Victorian Government*. https://www.ari.vic.gov.au/__data/assets/pdf_file/0023/746060/ARI-Technical-Report-389-Systematic-review-of-onshore-wind-farm-collisions.pdf

Mortality monitoring design for utility-scale solar power facilities: address the methodology needed to accurately estimate mortality of birds and bats at solar plants. *U.S. Geological Survey*. https://pubs.usgs.gov/publication/ofr20161087

R Data analysis packages for carcass detectability estimates: Miller, D.L. (2015a). Package 'Distance'. Version 0.9.4. Online manual downloadable at https://cran.r-project.org/web/packages/Distance/Distance.pdf
Miller, D.L. (2015b). Package 'mrds'. Version 2.1.14. Online manual downloadable at https://cran.r-project.org/web/packages/mrds/mrds.p

7.9 Mitigation

Mitigating biodiversity impacts associated with solar and wind energy development. This guidance provides tools, recommendations and examples of good practices to implement mitigation measures to renewable projects. *IUCN and The Biodiversity Consultancy*. https://portals.iucn.org/library/node/49283

TransMit: the evidence-based toolkit for mitigating power line-related avian mortality. *IUCN*. https://datazone.birdlife.org/tools/transmit

Options for biodiversity-friendly designs and approaches for offshore wind farms in Ireland: identified biodiversity-friendly offshore wind energy projects and initiatives both in Ireland and abroad. *Bluewise Marine*. https://bluewisemarine.ie/making-offshore-wind-work-for-nature-and-climate-in-ireland/#:~:text=Nature%2Dpositive%20design%20for%20offshore%20wind%20in%20Ireland&text=These%20solutions%20are%20well%2Dsuited,of%20offshore%20wind%20NBS%20grows

Biodiversity in solar parks: infographic and recommendations about the design of environmentally friendly solar plants. *NABU*. https://www.nabu.de/umwelt-und-ressourcen/energie/erneuerbare-energien-energiewende/solarenergie/31385.html

7.10 Repowering

The impact of repowering of wind farms on birds and bats: guidance assessing the best way for repowering of wind farms. *NABU*. Windkraft_LANU231106

Effects of wind turbine dimensions on the collision risk of raptors: A simulation approach based on flight height distributions. This scientific article provides information about the best height and size of the new turbines to reduce the probability of collisions of 6 raptor species based on GPS information. *Schaub et al*. https://www.sciencedirect.com/science/article/pii/S004896972406707X

7.11 Restoration, Offsetting and Biodiversity Net Gain

Compilation of Existing Guidance on Ecosystem Restoration: compiles general and country-specific recommendations and guides to perform better ecosystem restoration. *Ecologic Institute, Institute for European Environmental Policy and Trinomics*. https://www.ecologic.eu/19738

Working for biodiversity Net Gain: An Overview of the Business and Biodiversity Offsets Programme 2004-2018. It is an overview of best practices and guidelines to achieve no net loss through restoration and offsetting. *Secretariat of Business and Biodiversity Offsets Programme (BBOP).* https://www.forest-trends.org/bbop_pubs/overview2018/

Guidance Notes to the Standard on Biodiversity Offsets: is a compilation of principles with indicators and criteria for restoration and offsetting. *Secretariat of Business and Biodiversity Offsets Programme (BBOP).* Guidance Notes to the Standard on Biodiversity Offsets - Forest Trends

Agricultural Good Practice Guidance for Solar Farms. This guidance highlights the recommendations for including agriculture in solar plants. *BRE group and Solar energy*. https://files.bregroup.com/solar/NSC_-Guid_Agricultural-good-practice-for-SFs_0914.pdf

Integration of Crops, Livestock, and Solar Panels: A Review of Agrivoltaic Systems. It is a review of mitigation measures for solar energy infrastructures in combination with agrosystems. *Universidad Politécnica de Cartagena*. https://www.mdpi.com/2073-4395/14/8/1824

Statutory biodiversity metric tools and guides: provides several documents and tools used in England for measuring the biodiversity value of habitat for biodiversity net gain. UK Government (Department of Food & Rural Affairs) https://www.gov.uk/government/publications/statutory-biodiversity-metric-tools-and-guides

8 Examples of good practices

8.1 Power lines

8.1.1 Analysis of areas of sensitivity for birds due to electrocution and collisions with power lines in Morocco.

IUCN-Med, in collaboration with the Kingdom of Morocco's Department of Water and Forests, produced a map of sensitivity to power lines in 2021, the first of its kind for an African country.

The Moroccan electricity network currently covers nearly 360,000 km of transmission and distribution lines, with more than 99% coverage in rural areas. Between 2015 and 2019, some studies had been carried out by IUCN-Med, Moroccan government and national and international NGOs that revealed the existence of significant black spots of mortality in the centre and south of the country.

The work was carried out in four phases:

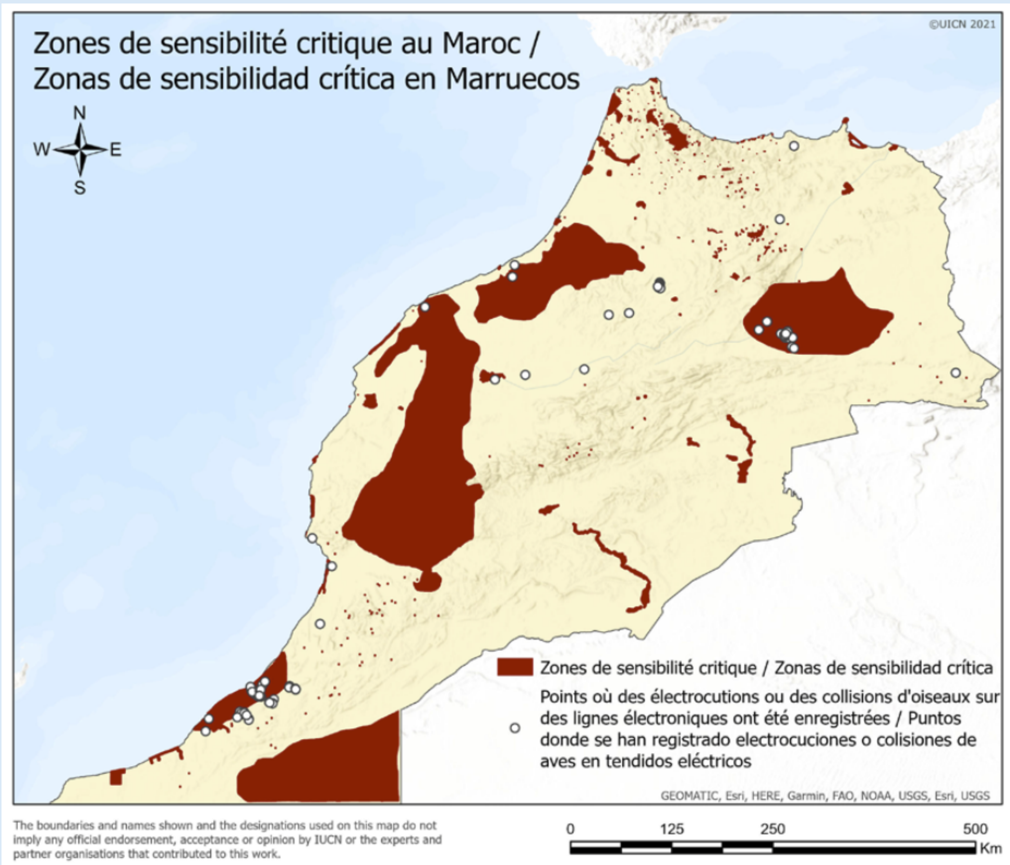
1. Selection of the list of bird species most sensitive to electrocution and/or collision accidents based on available information about their distribution.
2. Mapping of important areas for breeding, wintering, and congregation of individuals of these species.
3. Development and production of sensitivity maps and priority areas for implementing mitigation measures.

4. Definition of areas with the highest mortality risk based on the mapping of power lines and known incidents of deaths by collision and electrocution.

The sensitivity map was divided into five sensitivity zones: **Critical, High, Moderate and Low**. Each zone reflects a gradient of risk based on bird species presence and habitat types. Zones of Critical Sensitivity correspond mainly to wetlands, protected areas and steppe zones heavily used by species at high collision or electrocution risk (e.g., large raptors, storks, or cranes). High Sensitivity zones include key migratory corridors and areas of dense avian activity. Moderate to Low zones show lower but still notable levels of risk.

The mapping produced remains an initial assessment. Although the best available data and knowledge on the species have been used, for many birds the available information is scarce or inaccurate. Also, the analyses carried out lack the inclusion of the layout of power lines in the country, both existing and planned, due to the lack of or difficulty in accessing such cartographic information. Therefore, this mapping tool can be improved through the integration of new and better information in the future; the document also proposes the necessary steps to achieve this.

Nevertheless, the map is a useful tool for environmental planning and decision-making. It can help to prioritize mitigation measures, route planning, and conservation efforts, especially in zones with greater biodiversity and critical bird habitats. The zoning supports preventative strategies to reduce avian mortality related to energy infrastructure.



Source: IUCN (2022). Analyse des zones de sensibilité des oiseaux aux électrocutions et aux collisions avec les lignes électriques au Maroc. Gland, Suisse : IUCN.

8.1.2 Hungarian KEHOP-4.3.0 Overhead Power Line Conflict Mapping Study

The KEHOP-4.3.0 Overhead Power Line Conflict Mapping Study is a comprehensive strategic document that addresses the long-term mitigation of bird mortality caused by medium-voltage (10–35 kV) overhead power lines in Hungary. This study builds directly upon the 2008 conflict maps produced under the "Barrier-Free Sky Agreement" (Akadálymentes Égbolt Megállapodás), a voluntary collaboration between the Hungarian Ministry of Environment, the country's main electricity distribution companies (E.ON Hungária, ELMŰ-ÉMÁSZ, MVM DÉMÁSZ), and the Hungarian Ornithological and Nature Conservation Society (MME).

Since 2008, multiple LIFE and EEOP (Environmental and Energy Operation Programmes) -funded projects have implemented technical measures such as installing insulating covers, bird diverters, or converting overhead lines to underground cables. However, the spatial distribution of high-risk areas has evolved over the last decade, requiring a new, data-driven prioritization to support future investment and compliance with conservation objectives.

The methodology integrates extensive technical datasets provided by the distribution companies, covering over 53,000 km of medium-voltage network and more than 285,000 individual segments. These are analysed through a Geographic Information System (QGIS) combined with up-to-date ornithological databases from the MME Monitoring Center. The approach adopts a dual perspective: "macrohabitat" models capture the broader distribution of each priority species, while "microhabitat" models assess specific site conditions such as pole design, surrounding vegetation, and land use context (urban or rural).

A key innovation of this updated conflict mapping is its sophisticated scoring system for spatial prioritization. Each 2.5 x 2.5 km UTM grid cell is assigned a composite risk index by multiplying the ecological importance of the habitat (rated 1–5) by the species-specific vulnerability weight (also 1–5). This is done separately for electrocution and collision risk because these threats differ fundamentally in how they affect bird behaviour and population dynamics. For instance, species like the Imperial Eagle (*Aquila heliaca*) and the Saker Falcon (*Falco cherrug*) are highly susceptible to electrocution due to their perching habits on poles, while species such as the Great Bustard (*Otis tarda*) and migrating cranes (*Grus grus*) are more prone to collisions due to low-altitude flight across open habitats.

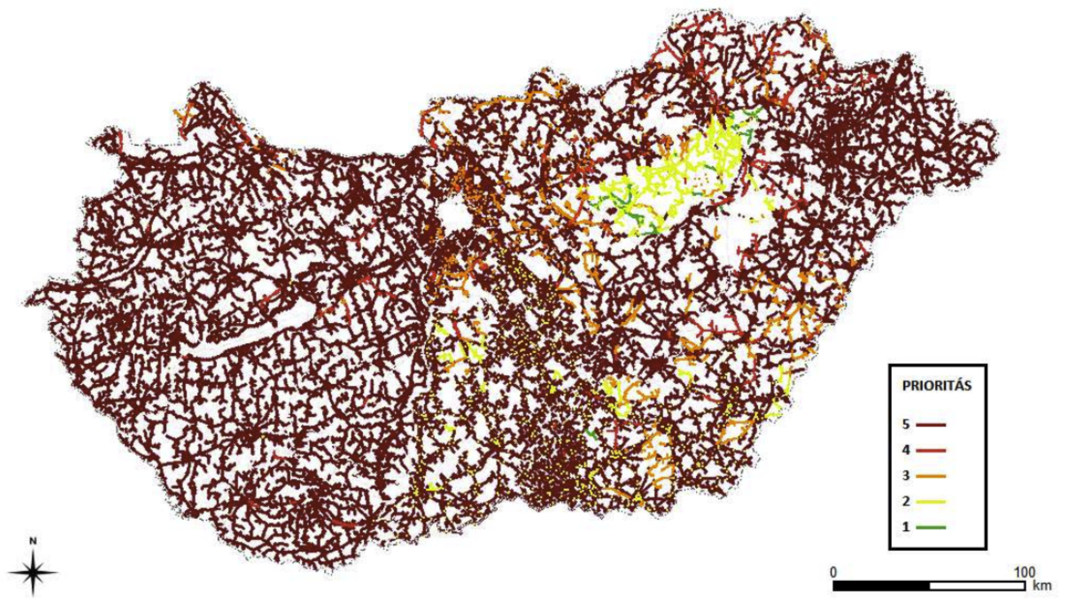
Additionally, a spatial buffering factor extends the analysis up to 10 km from each grid cell to account for the mobility of birds and the functional connectivity of critical habitats. This ensures that high-risk areas reflect both localized and landscape-scale patterns of use.

Once all grid cells are scored, the study advances from the initial 5-level classification (very high to very low priority) to a refined 20-category ranking. This percentile-based classification greatly enhances the practical applicability of the maps: by distinguishing the top 5% of conflict areas from intermediate or low-risk zones, operators and policymakers can design phased intervention plans that align technical feasibility with conservation urgency.

These conflict maps are cross-referenced with the current state of the power grid infrastructure. Each pole and line segment is matched with its corresponding UTM cell's priority score. Technical attributes, such as pole head design, presence or absence of insulation devices, and previous interventions, are analysed to identify gaps or obsolete measures that may need upgrading. This enables the creation of detailed inventories of "problem poles" and "critical sections," providing a clear blueprint for cost-effective mitigation actions such as retrofitting insulators, installing bird diverters, or replacing aerial lines with underground cables, particularly in urban areas where national regulations already favour underground distribution.

The report also highlights important contextual factors: rural and open areas pose inherently higher collision risks, especially in large agricultural landscapes and wetlands. In contrast, forested areas may reduce collision probability by naturally obstructing flight paths. These ecological nuances are incorporated as correction factors in the scoring model to better reflect real-world conditions.

The study underscores the need for periodic updates to the conflict maps as species distributions shift due to land use change, climate factors, or population recovery. Also, it calls for strengthened governance: clear phasing, measurable indicators, regular joint reviews by all signatory parties, and reinforced collaboration between grid operators, conservation authorities, and local communities.



51. ábra Magyarország középfeszültségű vezeték-hálózatának aktualizált térképe a beavatkozások műszaki tartalma szerint

Source: Solt, Sz., Horváth, M., & Tóth, P. (2021). KEHOP-4.3.0 szabadvezetékes elem konfliktustérkép tanulmány (Versión 1.0). Agrárminisztérium / MME – Magyar Madártani és Természetvédelmi Egyesület.

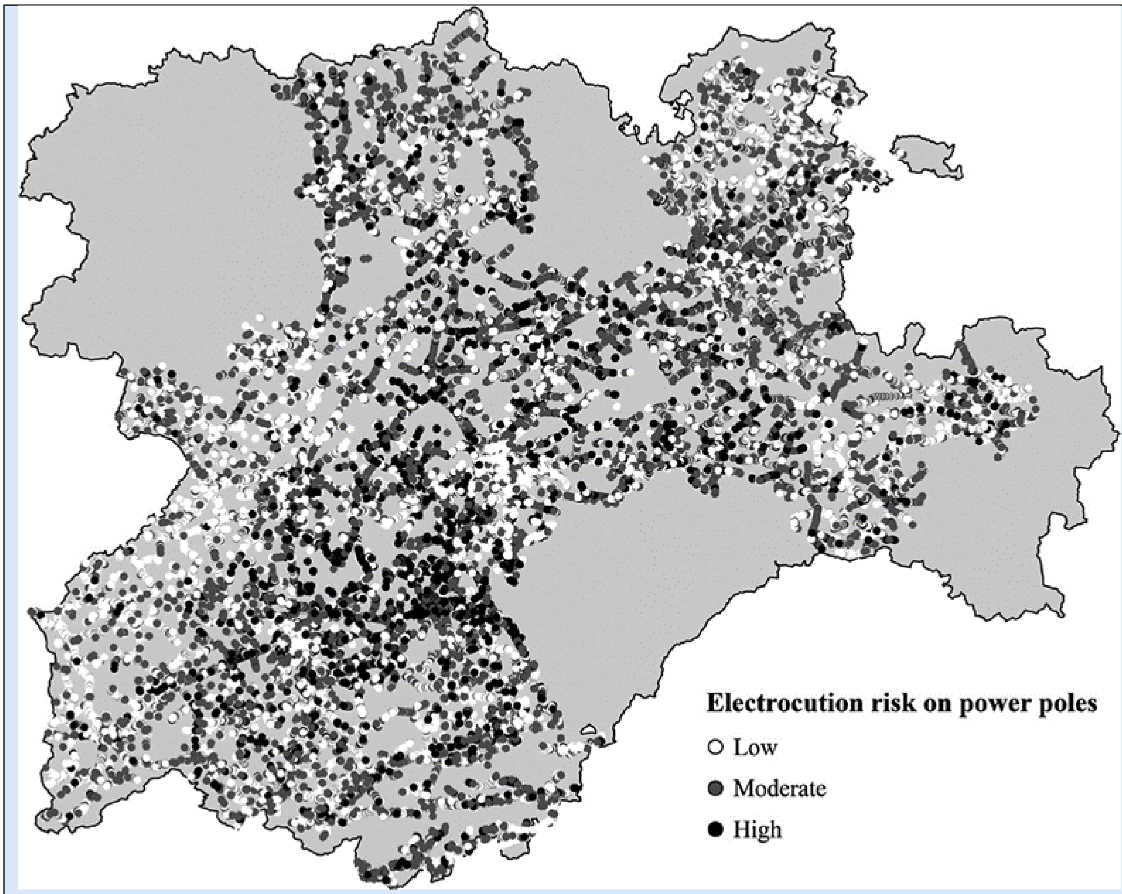
8.1.3 Zoning of the probability of electrocution for birds on power lines in Castilla-León (Spain)

The study recognises that the retrofitting of power poles to make them safe is costly and logistically demanding. So, the authors set out to develop a robust, spatially explicit model to help conservation managers and utility companies target those poles posing the greatest risk. The study demonstrates that combining habitat characteristics with detailed technical features of individual poles provides an accurate picture of where retrofitting efforts should be concentrated.

Working with data from nearly 190,000 power poles and verified records of electrocuted raptors in northwestern Spain, the researchers employed boosted regression trees (BRT) to model electrocution risk. Their final model identified that nearly 10% of poles posed high risk to raptors, with certain cross-arm designs, pole functions, and surrounding habitats — notably cropland areas and mid-level slopes — significantly increasing risk levels.

The practical utility of these findings is significant. First, electric companies can use this tool to prioritise retrofitting investments where they will save the most bird lives per euro spent, rather than applying blanket measures or waiting for incidents to occur. Second, wildlife managers can use the risk map to plan conservation actions proactively, aligning habitat protection measures with infrastructure modifications. Third, the method can serve as a decision-making guide for legal compliance, helping ensure that costly fines and environmental liabilities are minimised by targeting the riskiest structures first. Importantly, the approach can be readily updated with new field data, further improving its accuracy over time. The study also confirms that this modelling framework is scalable and adaptable to other regions and species, as it integrates species-specific traits like size and behaviour with infrastructure data.

Overall, the paper provides a science-based, actionable roadmap for balancing the demands of rural electrification with the conservation of vulnerable raptor populations. It highlights that achieving meaningful mitigation requires not just technical fixes but a clear understanding of how animals interact with their landscapes and the structures within them. By delivering a tool that identifies the worst offenders in a cost-effective way, this research empowers both utilities and conservation authorities to make smarter, more strategic choices — maximising conservation gains while optimising financial resources.



Source: Hernández-Lambraño, R. E., Sánchez-Agudo, J. Á., & Carbonell, R. (2018). Where to start? Development of a spatial tool to prioritise retrofitting of power line poles that are dangerous to raptors. *Journal of Applied Ecology*, 55(6), 2685–2697. https://doi.org/10.1111/1365-2664.13200.

8.1.4 Spain's Legislative Approach to Mitigating the Impact of Power Lines on Birds

Spain has played a pioneering role in addressing bird mortality caused by power lines, developed a comprehensive legal framework that combines national regulation with the implementation of European Union environmental directives.

The cornerstone of Spain's national regulation is Royal Decree 1432/2008, which establishes technical standards and obligations to protect birdlife from electrocution on power lines. This decree applies primarily to medium-voltage distribution networks and mandates the modification of hazardous pylons using bird-safe designs—such as insulated cables, suspended conductors, or elevated perches—to prevent birds from completing an electric circuit with their wings or feet. It also requires new infrastructure in sensitive areas to be designed in accordance with specific safety criteria. The decree identifies priority zones for action based on species vulnerability and conservation status, obliging regional governments to create inventories of dangerous supports and ensure retrofitting programs.

Beyond national legislation, Spain has actively aligned its policies with key European Directives, most notably the EU Birds Directive (Directive 2009/147/EC) and the Environmental Liability Directive (Directive 2004/35/EC). The Birds Directive has been a legal foundation for national conservation efforts and has prompted the designation of Special Protection Areas (SPAs) where bird-safe infrastructure is especially critical. The Environmental Liability Directive reinforces this by establishing a framework under which operators are financially and legally responsible for environmental damage, including harm to protected species caused by unsafe power lines.

More recently, it has included the application of Royal Decree 1432/2008 to industrial safety regulations for power lines, so that transport and distribution companies are obliged to implement preventive measures and promptly report any incidents they record so that the industrial authorities certify the proper functioning of the power line.

Failure to implement mandatory preventive measures in cases of continued mortality has led to numerous administrative proceedings resulting in heavy fines and the initiation of criminal proceedings (the Spanish code includes the death of endangered species as a crime).

The integration of these legislative tools has enabled Spain to achieve measurable progress. Thousands of hazardous pylons have been retrofitted across the country, especially in Natura 2000 sites, and mortality rates for key raptor species have declined in a lot of areas, promoting the recovery of species such as the Iberian imperial eagle (*Aquila adalberti*).

Download link of Royal Decree 1432/2008: https://www.boe.es/boe/dias/2008/09/13/pdfs/A37481-37486.pdf.

8.1.5 White book of electrocution in Spain

The **White Paper on Electrocution in Spain** represents the first formal, comprehensive national diagnosis of this conservation challenge. It was produced by conservation NGO GREFA in 2020, as an action of the European LIFE project AQUILA a-LIFE, and updated in 2022 to incorporate new data, recent legal cases, evolving regulatory frameworks, and improved corrective efforts.

The White Paper offers a **complete roadmap**: from understanding the problem's scale and legislative landscape to operational steps—mapping hotspots, enforcing corrections, securing funding, involving stakeholders, and tracking outcomes. Its ultimate goal is to substantially reduce bird electrocutions by improving infrastructure, regulation, governance, financing, and public awareness.

The White Paper was explicitly designed as a **national reference** and **action framework** to:

1. Provide a rigorous, updated diagnosis of a pressing conservation issue.
2. Inform and influence policy reform and related technical mandates.
3. Mobilize multistakeholder cooperation: regulators, power companies, conservation groups, engineers, and the public.
4. Catalyze the **prioritization, transparent public reporting**, and **financed correction** of hazardous electrical infrastructure.
5. Encourage innovation: deploying better materials, adopting efficient inspection (drones, GIS, mobile apps), and investing in I+D to support cost-effective mitigation.

The publication includes:

- A **detailed assessment of mortality**, including tables, spatial distribution maps, and risk categories identifying 17 "hotspots" of electrocution
- A review of **current legislation**, primarily Real Decreto 1432/2008, highlighting its deficiencies and the need to integrate the industrial technical standards
- An **economic analysis of investment effort in Spain to date**: 63.5 M € invested from 1996–2017, yet nearly 400,000 dangerous poles remain—requiring an estimated additional 755 M € to correct them.
- A set of targeted **recommendations**, segmented for environmental and industrial authorities, line owners, engineering bodies, manufacturers, NGOs, and citizen contributors.

Source: https://aquila-a-life.org/index.php/es/de-interes/multimedia/descargas/category/19-campana-de-educacion-ambiental-sobre-la-importancia-del-aguila-de-bonelli?download=503:libro-blanco-de-la-electrocucion-en-espana-analisis-y-propuestas-2022.

8.1.6 Le Comité National Avifaune (CNA) in France

The **Comité National Avifaune (CNA)** is a unique French cooperative platform established in 2004 that brings together major electricity network operators (originally EDF, now Enedis and RTE), leading wildlife protection NGOs such as the Ligue pour la Protection des Oiseaux (LPO) and France Nature Environnement (FNE), and, since 2013, the Ministry of Ecological Transition. The CNA specifically focuses on addressing the dual threats that overhead electrical infrastructure, including pylons and power lines, pose to bird populations, namely electrocution and collisions. Its main objectives are to reduce bird mortality associated with electrical networks by implementing coordinated, large-scale mitigation strategies; to share knowledge and best practices across regional and national stakeholders; to facilitate dialogue between network operators, environmental NGOs, and public authorities through regular meetings, supported since 2011 by an environmental mediator role; and to raise both public and sectoral awareness through publications, technical bulletins, and public conferences.

Among its key actions, the CNA promotes the installation of technical mitigation measures, such as visibility-enhancing bird flight diverters, like spirals and luminous "Firefly" markers, and insulating dangerous pylons to prevent electrocutions. It also supports research collaborations with institutions like the French National Museum of Natural History and CEFE to study collision impacts and integrate environmental criteria into grid planning. The CNA publishes regular information and training materials, including the "Oiseaux et lignes électriques" bulletins on thematic issues like raptor species or risk environments, and produces technical information sheets for professionals in the sector. Milestone public conferences, such as the 2009 colloquium and the 10-year review in 2014, have showcased results and charted new goals, while a recent event held on 25 November 2022 explored innovations and expanded the CNA's scope to European networks.

The CNA also supports European-scale initiatives such as the EU-funded LIFE SafeLines4Birds program, a six-year project launched in January 2023 with €14 million in funding, which aims to roll out thousands of "Firefly" markers, nesting platforms, and protective adjustments across France, Belgium, and Portugal. Over two decades, the CNA has matured into a model of cross-sector cooperation, linking NGOs, network operators, and government bodies to apply impactful, scalable mitigation strategies. By pooling technical solutions, facilitating knowledge exchange, and engaging diverse stakeholders, the CNA strives to significantly reduce bird mortality and to integrate avifauna safety into the planning and management of energy infrastructure both within France and across Europe.

Source: https://www.lpo.fr/la-lpo-en-actions/developpement-durable/energie/lignes-electriques.

8.1.7 LIFE Danube Free Sky

The LIFE Danube Free Sky project stands as a strong example of broad transnational cooperation. It brings together partners from seven countries (Austria, Slovakia, Hungary, Croatia, Serbia, Bulgaria, and Romania) and one non-beneficiary country (Germany). The partnership includes a diverse range of stakeholders: eight electric companies, one railway company, nature conservation authorities, local municipalities, and private non-commercial entities.

- The project is built on close collaboration among these stakeholders, aiming to:
- Contribute to the EU Biodiversity Strategy by halting the loss of biodiversity and ecosystem services along the Danube River
- Reduce and prevent both direct and indirect bird mortality caused by electrocution and collisions with power lines in 23 Special Protection Areas (SPAs) and 9 Important Bird Areas (IBAs)
- Increase the population of 12 target bird species
- Establish safer migratory routes and habitats along the Danube
- Strengthen cooperation among key actors and enhance the effectiveness of conservation measures at a transnational level.

Within the project area, approximately 2,074 km of eight types of above-ground power lines hazardous to birds have been identified. Additionally, around 10,909 potentially dangerous medium-voltage utility poles are located throughout the region. To identify the most hazardous of these, field surveys were conducted at the start of the project. To further support this effort, satellite transmitters will be deployed on juvenile birds to pinpoint dangerous poles within their home ranges and priority habitats.

During the initial recognition survey, over 1,380 km of power lines of various voltages and constructions were assessed across all participating countries. An international online GIS database was created in January 2022 to compile all field data. The monitoring protocol was updated accordingly to ensure proper implementation of the baseline survey.

As a result of this work, 34 mitigation plans were developed, essentially risk maps identifying high-conflict areas and specifying power lines where bird flight diverters should be installed.

By the end of the project, the visibility of over 245 km of high-priority power lines will have been significantly improved, and more than 3,200 of the most dangerous poles will be adjusted to ensure bird safety.

With the planned mitigation actions, insulating poles and installing diverters in the 23 SPAs and 9 IBAs, the project aims to prevent the death or injury of around 2,000 individuals of the target species each year, in addition to protecting many other bird species.

Source: https://danubefreesky.eu/en/

8.1.8 The NABU Bird Portal and RGI

Launched in 2017 by the Renewables Grid Initiative (RGI) and NABU, the Bird Portal is an innovative online platform developed to improve bird protection throughout Germany. Its primary goal is to collect data on bird fatalities caused by power lines by engaging the public in citizen science. Through the portal, individuals can report dead birds found near transmission or distribution lines, helping ornithologists identify dangerous areas where collisions or electrocutions occur. This public participation enhances data accuracy and helps guide targeted conservation actions.

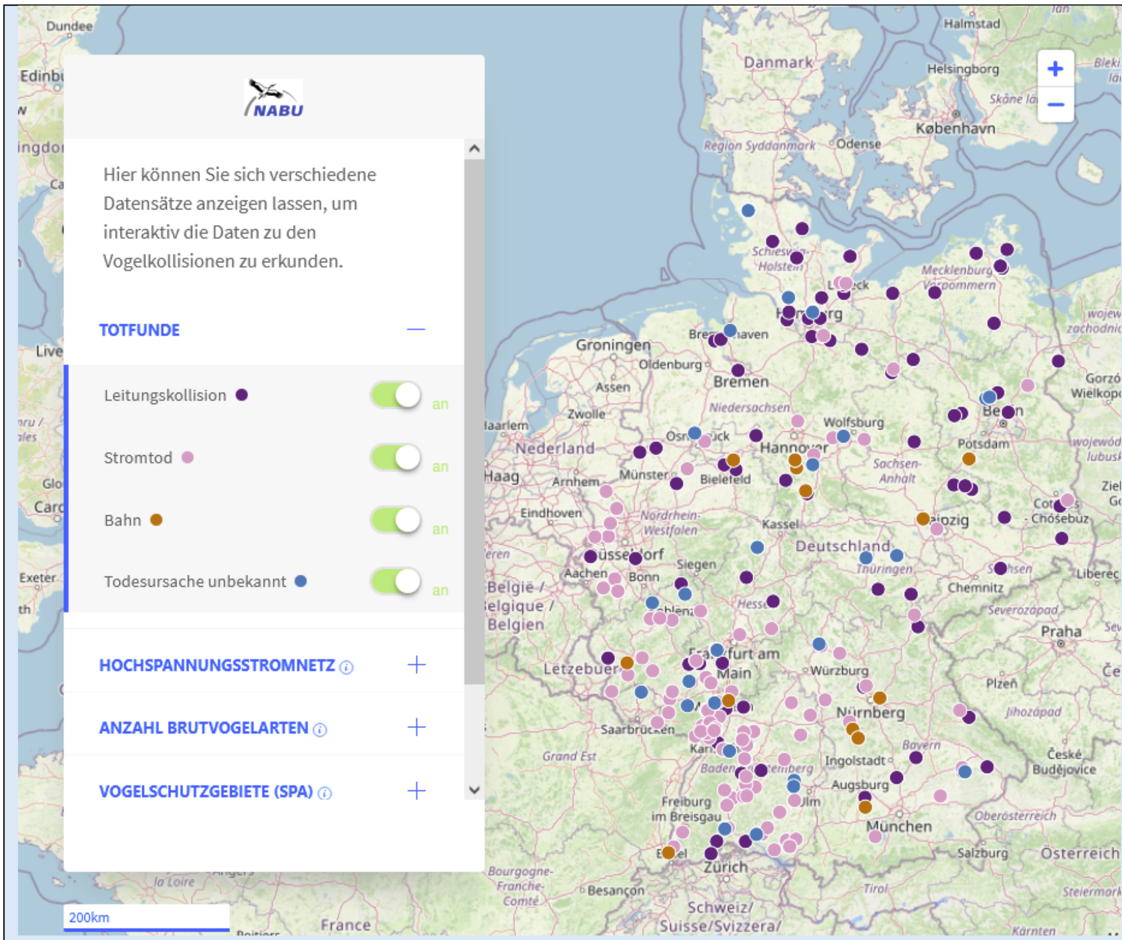
The Bird Portal brings a new level of effectiveness through large-scale, real-time data collection. It works through a simple process. When a member of the public reports a bird fatality, experts at NABU analyse the case, verify the details, and input the data into an interactive online map. This map then displays the reported incidents alongside existing power lines, bird habitat data (including Special Protection Areas), and records of species presence. The resulting geospatial overview allows grid operators to identify the most hazardous locations and prioritize them for mitigation measures, such as installing bird flight diverters.

The portal has gained strong institutional support. Seven major German grid operators are active participants, including four transmission system operators (50Hertz, Amprion, TenneT, and TransnetBW) and three distribution operators (Bayernwerk, Netze BW, and Westnetz). These companies use the portal’s findings to inform their planning and operational decisions regarding bird safety.

Beyond data collection, the Bird Portal has fostered a structured collaboration between NGOs and energy companies. A national working group has been established to share knowledge, review new mitigation technologies, and coordinate action. In September 2022, RGI and NABU co-hosted a national conference that brought together stakeholders from civil society, the energy sector, and public authorities to exchange ideas and improve bird protection practices.

Additionally, RGI has developed educational resources, such as the “Shared Airspace” video series and multilingual brochures, to raise awareness about the issue and promote bird-friendly infrastructure across Europe.

The Renewables Grid Initiative (RGI) is a one-of-a-kind partnership uniting NGOs and transmission system operators (TSOs) from across Europe in a shared “energy transition ecosystem.” Founded in 2009, RGI’s mission is to promote fair, transparent, and environmentally sensitive grid development that supports the integration of renewable energy The initiative fosters dialogue and collaboration, building support for the infrastructure needed to power a renewable-driven future. RGI pursues three core goals: demonstrating the need for grids, pioneering innovative planning and design approaches, and uniting diverse actors for policy and societal endorsement. Source: renewables-grid.eu.



Source:
https://www.nabu.de/tiere-und-pflanzen/voegel/gefaehrdungen/stromtod/25541.html.
https://renewables-grid.eu/

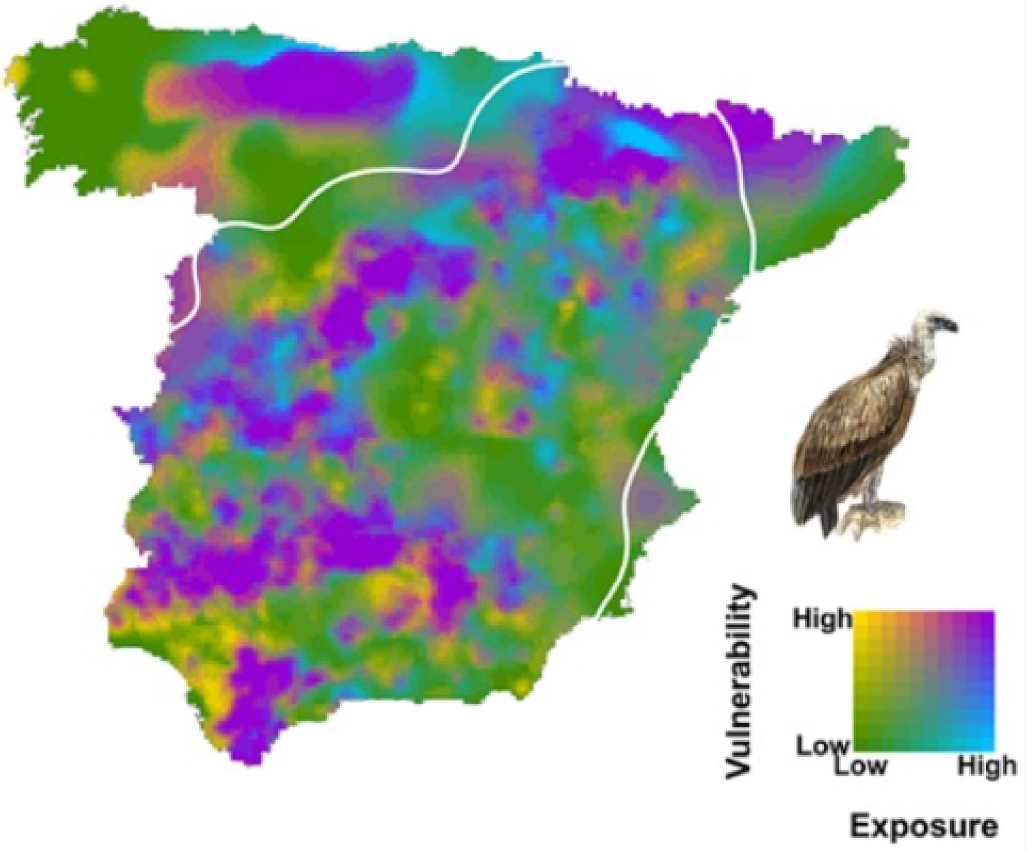
8.2 Wind energy

8.2.1 Fine-scale collision risk mapping for vultures

Sometimes, relatively abundant species, rather than endangered species, are threatened by renewable energies because of their sensitivity to these infrastructures. Griffon vultures show high wingspan loading and low manoeuvrability, soaring flights and a foraging behaviour, making this bird one of the highest registered mortalities in the wind farms of Spain.

Because of that, Jon Morant and colleagues from different research centres of Spain have developed a model to estimate the risk of collision of griffon vultures with wind farms in the Iberian Peninsula. Using information from more than 200 individuals marked with GPS devices, carcass availability, and monitoring population, they provide a collision risk model at the national level for this species. This model identifies the variables that increase the probability of occupation at a risk flight height (16 to 200 meters). Even more, they validated the model using recorded mortality during environmental surveillance.

This is an example of how high detailed information about target species from different methodologies and sources can be used to improve the assessment of new renewable energies locations, mitigating the impact on biodiversity. This project also highlights the relevance of sharing information to develop wide-range and accurate models rather than predictions from a few observations at specific conditions, only useful at local level.



Source: https://www.sciencedirect.com/science/article/pii/S0195925523003050

8.2.2 Drawing Migration Routes to assess the impact of Renewable energies in Türkiye

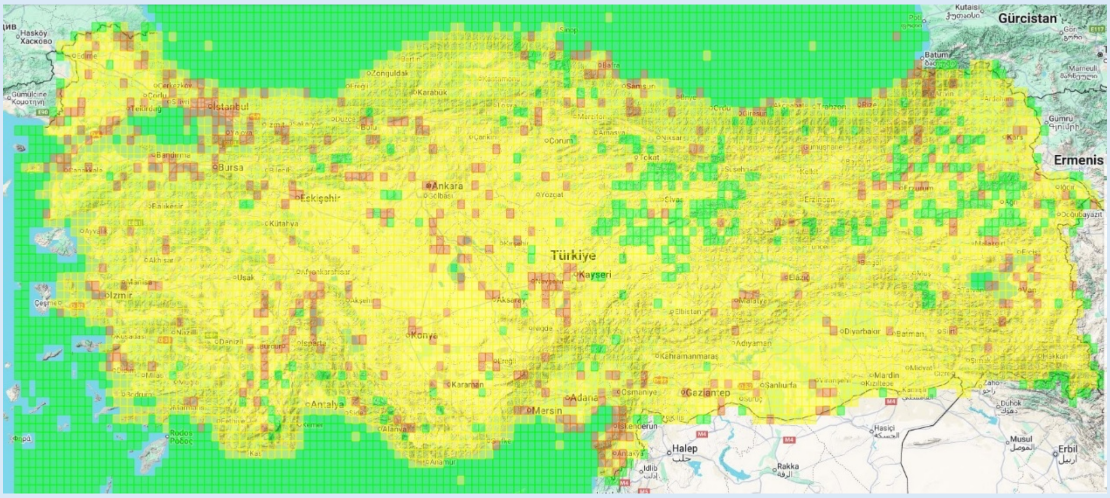
The project “Mapping Bird Migration Routes and Assessing the Impacts of Energy Investments on Bird Populations” was implemented across Türkiye under the coordination of the General Directorate of Nature Conservation and National Parks, Ministry of Agriculture and Forestry.

It addressed the growing conflict between renewable energy expansion and the conservation of migratory bird populations. Türkiye lies along one of the world’s most important flyways, and many areas suitable for wind energy development overlapped with migration corridors. This overlap created risks of habitat loss, displacement, barrier effects, and collision mortality.

To reduce these risks, the project produced comprehensive migration maps and intensity layers. Historical datasets, monitoring reports from existing and planned energy plants, and new standardized field surveys were compiled into a national database. Selected species were also tracked with satellite telemetry, providing detailed data on routes and stopover sites.
A key innovation was the use of artificial intelligence algorithms to process these data and automatically assess conflicts between proposed projects and bird populations. The system was integrated into Environmental Impact Assessment (EIA) procedures, enabling faster and more consistent evaluations.

The project delivered:

- A complete national map of bird migration routes.
- A centralized database and software to guide energy planning.
- More efficient EIA procedures, reducing delays while ensuring biodiversity safeguards.
- Stronger cooperation among government agencies, ornithologists, NGOs, and the energy sector.



By providing a transparent, science-based planning tool, the initiative aligned Türkiye’s renewable energy goals with the protection of migratory species, while supporting international commitments under the Bern Convention.

Source: https://www.tarimorman.gov.tr

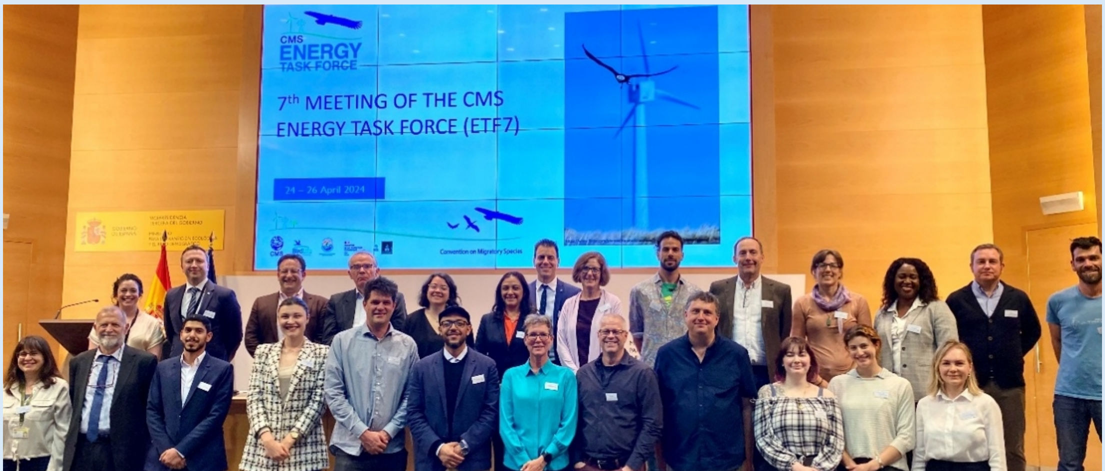
8.2.3 Energy Task Force (ETF)

NGOs or social responses to new renewable projects are one of the main troubles in the approbation process, which is a timely and costly effort. The Energy Task Force (ETF) is a multi-stakeholder group of work created by the Convention of Migratory Species of Wild Animals (CMS) in 2015. The aim of this work team is to ensure that renewable energy development encompasses the conservation of migratory species, which are among the most vulnerable species and usually depend on supranational agreements. For this purpose, they establish a rolling work plan for and regular meetings to discuss the new items of interest of the participants.

CMS Parties who are ETF members provide voluntary contribution to deliver the workplan.
The task force creates a space for dialogue involving the Secretariats of the participating Multilateral Environmental Agreements (MEAs), international organisations, international financial institutions, representatives of government in the field of environment and energy in the Parties to the participating MEAs, representatives of the energy industry, relevant academic institutions, civil society organisations, and other interested stakeholders.

In the last years, the task force has compiled relevant information on best practice policy and technical guidance, has promoted webinars and workshops about different topics, and has elaborated new guidelines and recommendations, mainly oriented to wind energy, solar energy and electricity grids, with expanding scope to marine species. Some notable publications include Post- construction Bird and Bat Fatality Monitoring for Onshore Wind Energy Facilities in Emerging Market Countries and Mitigating biodiversity impacts associated with solar and wind energy development.

Creating this kind of multi-stakeholder regular meetings and providing them with funds is essential to promote the participation of every stakeholder and advance with a common vision in the future of a nature-safe renewable energy transition.



Source: https://www.cms.int/en/taskforce/energy-task-force

8.2.4 Action protocol for conflicting wind turbines in Spain

Because of the distribution of wind turbines, extension of wind farms, or particularities of the landscape, the distribution of bird and bat mortality is not random in these facilities. One solution has been proposed by the Government of Spain.

This solution consists of a protocol for shutting down or dismantling the conflicting turbines based on the number of registered wildlife collisions with the turbines in the last five years and the species conservation status (**Error! Reference source not found.**).

This action addresses two objectives in bird conservation. First, this measure selectively and directly acts over the most dangerous wind turbines for wildlife conservation, avoiding a reduction in terms of energy production in the non-conflictive wind turbines. Secondly, this kind of measure encourages developers to increase their effort to detect potential negative impacts of renewable energies on birds and bats in pre-feasibility and baseline phases, selecting the best places and implementing the newest mitigation measures, to prevent the potential loss of energy and economic income of shut-down or dismantling of one or several wind turbines.

Furthermore, this protocol establishes a common regulatory framework, clarifying when and which measures need to be taken by the developers.

Table 2. Scheme of the Action protocol for conflicting wind turbines by the Government of Spain.

Conservation status	**Number of collisions**	**Consequences**
Endangered or Vulnerable species	1	Minimum of 3 months of shutdown
	2 (in 5 years)	Shutdown and population monitoring to determine the causes
	3 or more of the same species (in 5 years)	Permanent shut-down and possible dismantling
Non endangered but protected species		
All groups	1	• Analysis of the mortality causes and collision rate of each turbine • Compensatory and/or mitigation measure
Raptors	3	• Analysis of collision risk, population extinction risk, and population dynamics. • Minimum of 1 year of shutdown • Compensatory and/or mitigation measure (shutdown during migratory periods, scheduling operation according to biodiversity activity, etc.) • Evaluation of the effectiveness of adopted measures • Intensifying monitoring of mortality in the next 5 years • Potential dismantling of the turbine if the mortality continues exceeding the mentioned values.
Sea birds (gaviiformes, procellariformes y pelecaniformes), water birds (anseriformes, podiciformes, ciconiformes and phoenicopteriformes), waders and gulls (charadriiformes), cranes (gruiformes), steppe-birds (pterocliformes), and nightjars (caprimulgiformes)	5	
Galliformes, columbiformes, cuculiformes, apodiformes, coraciiformes, piciformes and paseriformes	10	
Bats	10	

8.3 Solar energy

8.3.1 Enhancement of bees and butterfly diversity

Promoting pollinators in solar farms involves a range of ecological and land management strategies designed to enhance habitat quality. These include planting native wildflower species at edges and corridors of solar plants that offer continuous nectar and pollen through the growing season, minimizing mowing intensity to allow flowering plants to thrive, and creating structural diversity through the inclusion of hedgerows, undisturbed soil patches, and microhabitats. Connectivity is crucial—linking solar parks with surrounding natural habitats via ecological corridors facilitates the movement of insects and supports ecosystem resilience. In Ireland, the All-Ireland Pollinator Plan has published specific guidelines for pollinator-friendly solar farms. These include avoiding use of pesticides, reducing mowing to once or twice a year, and leaving undisturbed soil for ground-nesting bees. One notable recommendation is ensuring that management actions align with local climate and flora. These guidelines are designed for both new and existing solar parks and are now being adopted by several developers and landowners.

In the UK, Solar Energy UK and the Solar Trade Association have reported that well-managed solar parks can host up to six times more pollinators than adjacent intensively farmed land. Practices include seeding with native perennial flowers, minimal soil disturbance during construction, and rotational grazing. Monitoring over several years has shown increased populations of bees, butterflies, and hoverflies, supporting the dual goal of clean energy generation and biodiversity recovery.

These examples demonstrate that biodiversity measures in solar PV projects are most effective when embedded from the design phase and maintained throughout operation. Benefits include enhanced biodiversity, reduced land management costs, improved soil and microclimate conditions, and even potential gains in panel efficiency due to cooler ground temperatures from vegetative cover. These initiatives show how solar energy and ecological restoration can go hand-in-hand across Europe.

Sources: All-Ireland Pollinator Plan; Solar Energy UK; Blaydes *et al*. 2022; and Blaydes *et al*. 2024.

8.3.2 Agrivoltaics in Netherlands

The company BayWa r.e. has launched one of its first commercial Agri-PV (agrivoltaic) sites in Babberich, the Netherlands, demonstrating the practical integration of solar power infrastructure with agricultural production. The underlaying idea of this type of solar plant is to mitigate the impact of land loss by solar panels and enhance agriculture fields, promoting the environmentally friendly facet of both human activities. This project builds on a series of pilot Agri-PV initiatives that BayWa r.e. has undertaken across the Netherlands and Germany.

In this case, they use semi-transparent panels and growth various types of crops under the solar panels. These pilot studies have been essential in advancing industry knowledge and were focused on a wide range of crops, including wheat, potatoes, celery, blueberries, red currants, raspberries, strawberries, and blackberries.

Through these projects, significant microclimatic benefits have been observed. On hot days, the temperature beneath the solar panels was consistently 2 to 5 Celsius degrees cooler than in open fields using traditional farming methods. This cooler environment helps to alleviate heat stress on plants and significantly reduces soil evaporation, resulting in lower water demand—an increasingly critical factor in sustainable agriculture. Furthermore, the data showed that at night, the solar panels retained heat more effectively than the plastic coverings typically used to shield berry crops from the cold. This suggests that Agri-PV systems could serve as a viable alternative to plastic coverings, potentially reducing plastic use on farms. Altogether, BayWa r.e.'s Agri-PV developments offer compelling evidence that solar infrastructure can enhance crop resilience, reduce environmental impacts, and promote sustainable land use practices.

Source: BayWa r.e. and RatedPower. Infography extracted from Integration of Crops, Livestock, and Solar Panels: A Review of Agrivoltaic Systems.

8.3.3 Grazing between solar panels in United Kingdom and Portugal

Lightsource BP, a joint venture between BP and solar developer Lightsource Renewable Energy, launched its largest United Kingdom-based solar energy initiative to date with the development of a 61 MW photovoltaic solar energy installation at Tiln Farm, Retford, Nottinghamshire. Spanning approximately 158 acres, the project was engineered to generate approximately 50 gigawatt-hours (GWh) of renewable electricity per year—equivalent to the annual power demand of 14,230 typical UK households—and to mitigate approximately 14,550 tonnes of CO_2 emissions annually.

The installation employed cutting-edge n-type Tunnel Oxide Passivated Contact (TOPCon) solar cell technology, known for higher efficiency and improved temperature performance compared to conventional p-type cells. The system was co-designed with agrivoltaic and ecological considerations, allowing for dual land use via sheep grazing, and including the establishment of approximately 10 acres of wildflower meadows and ecological buffer zones aimed at enhancing local biodiversity. The use of sheep avoids the use of pesticides and enhances biodiversity of beetles and other insects. This new grazing practice has clear positive externalities for the community. In addition to creating local jobs, it promotes other sectors such as livestock farming, providing nutrients to the soil and new seeds.

In Portugal, nearly 300 sheep currently graze within Iberdrola's photovoltaic (PV) parks, exemplifying a sustainable model through this practice. This agrivoltaic approach delivers multifaceted benefits: it provides livestock farmers with additional, cost-effective grazing land; it supports the ecological upkeep of solar installations by reducing vegetation and lowering wildfire risk without the use of pesticides; and it maximizes the use of space for human activities, reducing habitat loss.

At the Algeruz II photovoltaic facility—situated in the Setúbal district and comprising Iberdrola's first operational solar plant in Portugal with an installed capacity of 28 MW—approximately 200 sheep have already been integrated into the site. A further 70 sheep graze at the Conde PV plant in Palmela, completed in the previous year.

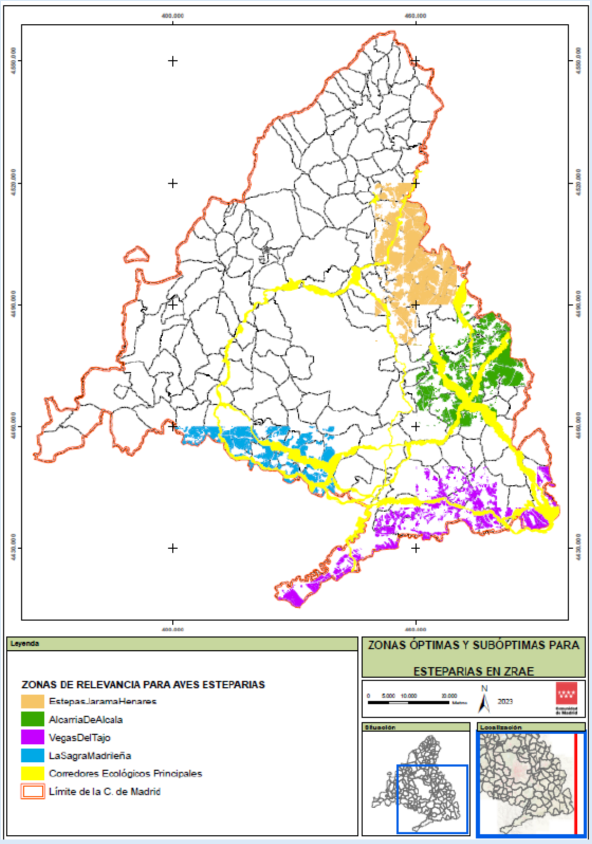
Beyond the immediate operational advantages, grazing at solar farms contributes to soil regeneration, sustains traditional hunting practices, and strengthens rural economies.

Source: https://lightsourcebp.com/es/project/tiln-farm-solar/; https://www.iberdrola.com/press-room/news/detail/iberdrola-launches-a-solar-grazing-in-portugal-with-some-300-sheep

8.3.4 Offsetting for Steppe-Birds in Madrid (Spain)

The Agri-Environmental Programme for the Promotion of Crops Compatible with the Presence of Steppe Birds in the Framework of Compensatory Measures for the Deployment of Renewable Energies in the Community of Madrid (Spain) is led by the Directorate-General for Biodiversity and Natural Resources of the Community of Madrid, aims to halt the decline of steppe bird populations by promoting agricultural land management practices compatible with their conservation. It focuses on priority species such as great bustard (*Otis tarda*), little bustard (*Tetrax tetrax* – critically endangered), Montagu's harrier (*Circus pygargus* – vulnerable), hen harrier (*Circus cyaneus*), lesser kestrel (*Falco naumanni*), black-bellied sandgrouse (*Pterocles orientalis* – vulnerable) and pin-tailed sandgrouse (*Pterocles alchata* – vulnerable), as well as associated farmland biodiversity.

The programme is spatially targeted to four *Steppe Bird Relevance Areas* (ZRAE) — Jarama–Henares steppes, Alcarria de Alcalá, Tajo valley plains, and La Sagra Madrileña — plus ecological corridors specifically designated for steppe birds. At least 75% of the compensatory measures required from photovoltaic plants and associated evacuation infrastructures must be implemented within these ZRAE, with the remaining ≤25% in nearby priority habitats.
Compensation requirements are standardised for all promoters, with surfaces calculated according to habitat loss and specific correction factors for sensitive areas. The investment rate is set at €600/ha/year, and for high-risk aerial line installations in sensitive areas, compensations include retrofitting 30 dangerous poles for every new one installed.



Designated Steppe Bird Relevance Areas (ZRAE)
Community of Madrid Agri-Environmental Programme

Implementation is coordinated through accredited land stewardship entities with proven experience in steppe bird conservation, working in partnership with promoters' environmental technicians, sectoral NGOs, farmers, stockbreeders, and hunting estate managers. These actors sign voluntary long-term custody agreements ensuring compatibility with Common Agricultural Policy subsidies while enhancing environmental ambition.

Measures include environmental fallows, wildlife-friendly cereal cultivation, biodiversity margins, organic management of traditional olive groves, water points for fauna, creation of mosaic landscapes, and extensive grazing regimes. The programme integrates monitoring, adaptive management, and public awareness actions. Annual plans are reviewed and validated by the competent authority, with a five-year population assessment to adjust strategies and investment requirements if necessary.

Source: https://gestiona.comunidad.madrid/cove_webapp_codigoverificacion/#/acceso-qr/1038081177702258593729

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